Department of Energy

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208-3621

FREEDOM OF INFORMATION ACT PROGRAM

November 29, 2019

In reply refer to: FOIA #BPA-2019-01037-F

Albert O'Connor
Washington Waterfowl Association
[redacted]

Dear Mr. O'Connor:

This communication is the Bonneville Power Administration's (BPA) final response to your request for agency records made under the Freedom of Information Act, 5 U.S.C. § 552 (FOIA). Your request was received on June 16, 2019, with a formal acknowledgement letter sent to you on June 25, 2019.

Request
"[Referencing]… the Steigerwald Lake Floodplain Restoration Project, Final EA on page 3-26, para 3.5.1.1.1, paragraph 2, [wherein] it was stated: 'Critical habitat for LCR Chinook includes the Columbia River adjacent to the study area but does not include the Refuge lands other than Gibbons Creek' [, I] [r]equest all information including studies, scientific data, and reports that were the basis of the LCR Chinook use of Steigerwald Lake Refuge."

Response
BPA conducted a search of the electronic record files in the Environmental Compliance Fish & Wildlife Office. Responsive records comprised of 161 pages were located. BPA is herein releasing the 161 pages of agency records responsive to your FOIA request, with no redactions applied. BPA notes that the released version of the Wolf Water Resources' Steigerwald Floodplain Restoration Project report has the appendices omitted. That record is the sole available version of the record the agency has to provide.

Fees
There are no fees associated with the fulfillment of your FOIA request.

Certification
Pursuant to 10 C.F.R. § 1004.7(b)(2), I am the individual responsible for the records search and release determinations described above. Your FOIA request BPA-2019-01037-F is now closed with all available agency records provided.

Appeal
The adequacy of the search may be appealed within 90 calendar days from your receipt of this letter pursuant to 10 C.F.R. § 1004.8. Appeals should be addressed to:

Director, Office of Hearings and Appeals
HG-1, L'Enfant Plaza
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585-1615

The written appeal, including the envelope, must clearly indicate that a FOIA appeal is being made. You may also submit your appeal by e-mail to OHA.filings@hq.doe.gov, including the phrase "Freedom of Information Appeal" in the subject line. (The Office of Hearings and Appeals prefers to receive appeals by email.) The appeal must contain all the elements required by 10 C.F.R. § 1004.8, including a copy of the determination letter. Thereafter, judicial review will be available to you in the Federal District Court either (1) in the district where you reside, (2) where you have your principal place of business, (3) where DOE's records are situated, or (4) in the District of Columbia.

You may contact BPA's FOIA Public Liaison, Jason Taylor, at the address at the letter header for any further assistance and to discuss any aspect of your request. Additionally, you may contact the Office of Government Information Services (OGIS) at the National Archives and Records Administration to inquire about the FOIA mediation services they offer. The contact information for OGIS is as follows:

Office of Government Information Services
National Archives and Records Administration
8601 Adelphi Road-OGIS
College Park, Maryland 20740-6001
E-mail at ogis@nara.gov
Telephone at 202-741-5770
Toll free at 1-877-684-6448
Facsimile at 202-741-5769

Questions about this communication may be directed to Thanh Knudson, Flux Resources, LLC, assigned to the BPA FOIA Office, at etknudson@bpa.gov or 503-230-5221.

Sincerely,

Candice D. Palen
Freedom of Information/Privacy Act Officer

Responsive records accompany this communication in electronic format.

ESA

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technical memorandum

date June 13, 2016

to Chris Collins, Project Manager
Lower Columbia Estuary Partnership

from Linda Mark, LG, CPG
Curtis Loeb, PE
Ken Vigil, PE

subject **Steigerwald Floodplain Restoration Project**
Hydraulic Analysis of Gibbons Creek

1. Introduction

Restoration of the Steigerwald National Wildlife Refuge (Refuge) is intended to restore floodplain processes and habitat connectivity between the Columbia River, its historic floodplain, and Gibbons Creek. The general restoration plan is shown in Figure 1. Primary actions of the plan include:

- Removing approximately 2.2 miles of the Port of Camas-Washougal (Port) levee;
- Restoring large floodplain channels that connect the Refuge to the river;
- Constructing two setback levee segments to maintain flood risk reduction for Port and City of Washougal (City) properties near the west levee and an adjacent landowner near the east levee;
    - The west setback levee would include a floodwall along Gibbons Creek to decrease flood risk for the Gibbons Creek Mobile Estates and adjacent landowners;
    - The west setback levee would also include a closure structure across Washington State Route 14 (SR 14) at approximately milepost 18 that would be require installation during Columbia River stages above the 500-year flood stage;
- Raising the SR 14 roadway elevation approximately three feet (to the 500-year flood elevation) to reduce Columbia River flooding, overtopping, and wave-related erosion and debris maintenance;
- Reconnecting Gibbons Creek so that it flows directly to the river through removal of all diversion infrastructure (water control structure, fish screen, sedimentation basin, elevated canal, and the fish ladder and culvert near the river); and,
- Several other recreation and public access enhancements in the Refuge.

The purpose of this technical memorandum is to characterize the hydraulic conditions of Gibbons Creek in support of the restoration project. Hydraulic analysis compares existing (without project) and proposed (with project) creek conditions under a range of hydrologic conditions. The analysis is intended to support US Army

Corps of Engineers (USACE) and other stakeholder reviews of the project, as well as support the design of the creek flood risk reduction elements. The scope of the hydraulic analysis includes:

- Develop a hydraulic model of Gibbons Creek, extending from upstream of the BNSF Railway and Evergreen Highway Bridges to Steigerwald Lake in the central portion of the Refuge.
- Consider a range of Gibbons Creek / Columbia River coincident conditions up to combined 500-year recurrence interval conditions.
- Characterize hydraulic conditions in the creek under proposed conditions to ensure sediment transport and deposition in appropriate reaches of the creek.
- Estimate the existing and proposed capacities of the Gibbons Creek channel below the SR 14 bridge
- Confirm / determine adequacy of the elevations of the closure structure across SR 14 and the flood structures (floodwall and earthen berm) along the west bank of Gibbons Creek upstream of SR 14.
- Support design of:
    - Scour protection elements for the SR 14 embankment and bridge, and the floodwall and earthen berm along the creek;
    - Gibbons Creek channel and floodplain;
    - Seepage cutoff measures for the Gibbons Creek floodwall.

2. Site Hydrology

2.1. Gibbons Creek

Gibbons Creek is a small tributary to the Columbia River located in southwest Washington, east of the town of Washougal. The creek drainage area is approximately 7.2 square miles (USGS 2016; USACE 2012). The creek flows generally south through the west end of the Columbia River Gorge, and into the Steigerwald National Wildlife Refuge, before entering the Columbia River. The peak elevation in the Gibbons Creek watershed is approximately 1,170 feet, and precipitation generally falls as rain. Mean annual precipitation is over 70 inches, with peak rainfall occurring during winter months (LCEP 2015). The southern portion of the Gibbons Creek watershed is relatively urbanized, and the remainder of the watershed primarily consists of rural residential properties.

2.1.1. Flow Control Infrastructure

As Gibbons Creek nears the Refuge, the creek begins to flow across its historic alluvial fan. The position of the creek within its alluvial fan has been constrained by several transportation corridors: the Evergreen Highway, the BNSF railway, and State Route (SR) 14 (see Figure 2). Immediately downstream of SR 14, Gibbons Creek flows into a diversion structure which includes an elevated canal, water control gate, fish screen, and lateral overflow. The purpose of the diversion structure is to reduce creek flows entering the interior drainage of the levee because the drainage requires management by the Port of Camas-Washougal. The flow control gate allows up to 70 cubic feet per second (cfs) of the creek to enter the elevated canal, also referred to as the Highland Canal. The Highland Canal is approximately 6,000 feet long, and bisects Steigerwald Lake before discharging through an 84-inch culvert (through the levee), over a fish ladder, and then into the Columbia River. Flows above approximately 70 cfs spill over a concrete apron and/or through a fish screen and into the Gibbons Creek remnant channel. Flows in the remnant channel eventually reach the Port's drainage culvert and pump station at the west end of the industrial park (USACE 2012).

The US Fish and Wildlife Service (USFWS) operates and maintains the Gibbons Creek diversion structure and Highland Canal. During storms, bedload and debris from the creek commonly get deposited within the structure. The sediment and debris can then cause modest flows (less than 70 cfs) to spill into the lateral overflow and remnant Gibbons Creek channel where they must be pumped through the levee to the Columbia River. USFWS staff regularly remove sediment and debris from the channel to minimize overflows and to maintain conveyance below the SR 14 Bridge (ESA 2016).

2.1.2. Peak Flows

Gibbons Creek does not have a long term record of continuous flow or water level data. Peak flows estimates for the creek were documented by the USACE in a 2012 planning assistance study to support the Port using a rainfall-runoff simulation model, HEC-HMS (USACE 2012). The peak flows from the watershed study are listed in Table 1. These values are based on the revised hydrology scenario that includes updated watershed development and are reported at the SR 14 Bridge.

Table 1 Gibbons Creek Flow Estimates.

Flow Parameter / Recurrence Interval	Flow[1] (cfs)	2080 Climate Change Projection[2] (cfs)	Notes / Reference
Base Flow	< 10	N/A	Estimated from field observation
1.01-Year	200	240	Engineering Estimate
2-Year	320	380	USACE updated hydrology
5-Year	530	640	USACE updated hydrology
10-Year	670	800	USACE updated hydrology
50-Year	1,00	1,200	USACE updated hydrology
100-Year	1,140	1,370	USACE updated hydrology
500-Year	1,470	1,760	USACE updated hydrology

[1] (USACE 2012)
[2] (Mauger and Tohver 2013)

For general comparison, the peak flows from the USACE study were compared to estimates based on USGS StreamStats regional regression relationships (USGS 2016) and peak flows calculated from long term observed records in several nearby gaged basins (as described in ESA 2015). The USACE estimates were slightly lower than those from the USGS regressions and the gaged data for the 2- through 10-year flows by approximately 17 to 21 percent; however, the USACE estimates fell between the USGS and gaged data-based estimates for the 50-, 100- and 500-year recurrence intervals. These comparisons provide improved confidence in the Gibbons Creek flow estimates, which is important when considering flood risk reduction measures for properties and infrastructure adjacent to the creek.

2.1.3. Effects of Climate Change

Creek Hydrology

Few published studies in the Pacific Northwest have evaluated the effects of climate change on flood hydrology of small basins such as Gibbons Creek. One recent study by the University of Washington Climate Impacts Group (CIG) considered changes in extreme flows due to climate change for two coastal watersheds in Northwest Oregon (Mauger and Tohver 2013). Though these watersheds (the Miami and Kilchis) are part of the Coast Range and are approximately 75 miles away from the Gibbons Creek Watershed, they are relatively similar in latitude, basin size, elevation range, and precipitation distribution to those of the Gibbons Creek Watershed. Thus, the basins in the CIG study provide a general estimate of potential changes in peak streamflow hydrology.

The CIG study evaluated changes in flooding for the 2-, 5-, and 50-year recurrence intervals of annual peak daily flows over the 2040, 2050, and 2080 horizons. The study considered the A1B (medium emissions) scenario from both the Columbia Basin Climate Change Scenarios Project (CBCCSP; Salathé et al. 2013) dataset and the Weather Research and Forecasting (WRF) regional model dataset (Roeckner et al. 1999; 2003). Changes in flooding were projected to be modest, with large variation among model projections. There is a tendency towards increases in flooding, with the magnitude of change greatest for more extreme flow metrics (i.e., 50-year flood). The projected percent changes in peak flow magnitudes varied among downscaled model datasets, recurrence intervals, and future horizons:

- 2-year flow: 8 – 17 percent increase
- 5-year flow: 9 to 20 percent increase
- 50-year flow: 13 to 29 percent increase

To simplify estimates for Gibbons Creek, a general increase of 20 percent was applied across recurrence intervals. This percent increase was close to the upper end of the ranges predicted, and it was consistent with results assuming the longer term 2080 horizon. The resulting 2080 peak flows reflecting anticipated climate change effects are shown in Table 1.

Columbia River Stage & Climate Change

The specific effects of climate change on Columbia River flood stages are complicated due to numerous factors including flood storage capacity assumptions and variability in predicted snow/rainfall - runoff timing and magnitude. Published future projections of changes in flood stages in the river are not yet available. Thus, estimation of expected future changes in Columbia River flood conditions is beyond the scope of this analysis, and climate change impacts on stages in the Columbia River are not included.

2.2. Columbia River Flood Stages

After restoration, the Columbia River would flood into the Refuge during winter storm and freshet conditions. Columbia River flood levels are defined by the US Army Corps of Engineers (USACE) according to combined probability flood profiles (USACE 2007). Flood levels in the river at the Refuge are complicated because they are dependent on upstream flows from Bonneville Dam as well as other factors including varying tides downstream in the river-estuary, the Willamette River, and other tributary inflows such as the Sandy River (USACE 1989). The USACE flood profiles are based on observed water level data from stations along the river as well as hydraulic modeling. Flood water levels in the river at roughly the west setback levee and Gibbons Creek location (River Mile 125.5) are summarized in Table 2. The combined probability profiles are shown in Figure 3.

Table 2 Summary of Existing Columbia River Water Levels and Site Features at Steigerwald NWR.

Feature / Water Level	Elevation* (feet NAVD88)	Source and Notes
Levee Crest (West Levee)	45.7	USACE 1989**; Cornforth 2012
Levee Design Flood (LDF)	41.46	USACE 1989**; Cornforth 2009
500-year Water Level	38.5	USACE 2007**
SR 14 Low Point	35.2	USACE LiDAR 2010; SWLS 2015
100-year water Level	35.1	USACE 2007**
50-year water Level	33.8	USACE 2007**
5-year water Level	28.0	Not included in flood profiles; based on engineering estimate
2-year water Level	26.9	USACE 2007**
1.01-year water Level	18.0	Not included in flood profiles; based on engineering estimate

*Columbia River water surface elevations at the middle of the Refuge at RM 125.5 (near the west setback levee and closure structure, and roughly in line with the Gibbons Creek bridge).

**Regulated (post 1976 conditions – 14 dams, 39.7 MAF storage) flood frequency profiles based on storage-frequency relationships, unsteady flow model (DWOPER) and engineering judgment. River Miles correspond to NWRBC (June 1962).

2.3. FEMA Flood Study

The Columbia River base flood (1% annual chance or 100-year event) extents and floodway in the vicinity of the Refuge are described in the FEMA Clark County Flood Insurance Study (FIS). The base flood elevation in the river varies from elevation 36 feet NAVD88 at the upstream extent of the Steigerwald floodplain near Lawton Creek, to elevation 35 feet NAVD88 near west end of the levee system. These values were derived directly from the USACE combined probability flood profiles for the Lower Columbia River described in the previous section. Hydraulic modeling was not performed to determine flood profiles. For the Columbia River, a HEC-2 hydraulic model was used only for the floodway determination in the FIS. Per the FIS, the discharges used in floodway computations for the Columbia River were correlated, based on data at USGS gage No. 14105700 (established in 1857) at The Dalles, to yield water surface profiles similar to those prepared using the FEMA (2012) combined probability stage-frequency curves.

Gibbons Creek is not mapped in the FIS and Flood Insurance Rate Maps (FIRMs; FEMA 2012). The creek is outside the area of detailed study. The interior drainage within the Washougal Flood Damage Reduction (FDR) levee is mapped as Zone A (no base flood elevations determined), though the 2012 Port of Camas-Washougal levee certification documents the interior base flood elevation as elevation 22.4 feet NAVD88. The FEMA floodplain map information is shown in Figure 4.

3. Hydraulic Model Development

A hydraulic model was developed using the USACE Hydrologic Engineer Center River Analysis System (HEC-RAS) computer program (HEC 2010, version 4.1.0). The model was developed to simulate one-dimensional, steady state, gradually-varying flows in Gibbons Creek. The program is well-suited for this application because it is capable of representing numerous types of hydraulic structures including bridges, lateral weirs, in-line weirs, and storage areas found in Gibbons Creek.

3.1. Existing Conditions Geometry

The existing conditions geometry of the Gibbons Creek model is based primary on detailed ground survey by professional land surveyor Statewide Land Surveying, Inc. (2015). The creek and adjacent areas were surveyed beginning in July 2015, with supplemental surveys continuing through early 2016. The topographic survey of the creek included:

- Control points along the creek and near the SR 14 Bridge over the creek
- Gibbons Creek channel
    - Cross section spacing of 40 to 60 feet
    - Tops of bank of the creek on both sides
    - Creek floodplain widths of 150 feet upstream of SR 14, and widths of 300 feet downstream of SR 14
- Bridges
    - BNSF Railroad Bridge near the upstream model extent
    - Small footbridge immediate downstream of the BNSF Bridge (not included in the model though the nearby channel geometry was included)
    - SR 14 Highway Bridge
- SR 14 roadway embankment
    - Over 2,000 feet of the road surface, driveways, and embankment
    - Extending from 45th Street west of the Gibbons Creek SR 14 Bridge approximately to the USFWS Refuge visitor parking lot driveway
- Diversion structure
    - Concrete overflow apron
    - Fish screen
    - Water control structure at the head of the elevated canal
    - Elevated canal channel and embankment
- Datums and units
    - Horizontal datum: Washington State Plane Zone south, US survey feet
    - Vertical datum: NAVD88 in units of feet

The Gibbons Creek channel below the SR 14 Bridge was surveyed in October 2015. The creek channel thus reflects conditions after the prior year's maintenance dredging had occurred. This condition was confirmed through site observations and photos in October and November showing no significant deposition in the channel or overflow weir downstream of the bridge. The implication is that post-storm sediment deposition in the channel and below the bridge can significantly reduce bridge capacity and raise water surface elevations beyond those reflected in this analysis.

Supplemental topography data were also developed for areas beyond the detailed ground survey. LiDAR data (Watershed Sciences 2010) and photogrammetry data (SWLS 2015) were used in these areas. The main areas where the topography was defined by either LiDAR or photogrammetry include:

- **Photogrammetry**
  The USFWS field located east of the creek, between SR 14 and the BNSF Railway. This region is the floodplain of the creek, though flow does not enter this region commonly due to the high banks of the creek.
- **LiDAR**
  Gibbons Creek Mobile Estates properties located west of the creek between SR 14 and the BNSF Railway. This region also does not get inundated frequently due to the relatively high bank of the creek.

The overall project survey report and Gibbons Creek survey drawings are included in **Appendix A.** The HEC-RAS model geometry schematic is shown in Figure 5**.**

3.2. Hydraulic Structures

Hydraulic structures that are part of the Gibbons Creek model include the BNSF Railroad/Evergreen Highway and SR 14 Bridges, the water control structure upstream of the Highline Canal, the fish screen, and the concrete overflow weir downstream of SR 14. Representation of these hydraulic structures in the model is summarized in **Error! Reference source not found.**. The model schematic of the SR 14 Bridge is shown in Figure 6.

Fish Screen

Fish screens are complex hydraulic structures and are not among the flow control options in HEC-RAS. The Gibbons Creek fish screen was represented in the model as a lateral overflow weir with a single, rectangular culvert. The culvert was sized to provide an equivalent open area to allow flow through the structure at the appropriate elevations; the culvert span of 18.0 feet divided by screen length of 44.6 feet equals an open area ratio of 0.4. A schematic of the fish screen in shown in Figure 7.

Several USACE and other sources were used to estimate equivalent screen open areas for perforated plate screens. Values ranged from 0.27 to 0.5 (WDFW 2000; Miller et al. 2010; CADFW 2016; USACE 2014). A value of 0.4 (40%) was selected for the Gibbons Creek screen based on:

- field observations of flow and head loss during high and low flows,
- this value being intermediate with the cited literate range,
- considering the screen is a relatively modern structure likely designed for juvenile fish (near the upper end of the open area range), and
- model calibration described in Section 4 which showed a reasonable comparison of simulated and observed water surface elevations.

Table 3 Summary of Existing Hydraulic Structures in the Gibbons Creek Model.

Structure / Component	River Station	Value	Notes
BNSF Railroad/Evergreen Hwy Bridge: Length Distance between abutments Low chord elevation Deck elevation Channel thalweg elevation at structure	2928.00	113.4 ft 22.8 ft 52.35 ft NAVD88 (US & DS) 55.5 ft NAVD88 44.8 – 45.0 ft NAVD88	Modelled as single bridge
SR 14 Bridge: Length Length between piers Low chord elevation Deck / road elevation Channel thalweg elevation at structure	1687.00	40.2 ft 47.2 ft (US) 36.10 ft NAVD88 / (DS) 36.21 ft NAVD88 38.2 ft NAVD88 31.40 - 32.27 ft NAVD88	
Concrete overflow weir: Width Length Apron crest elevation Channel thalweg elevation at structure	1587.26	21.7 ft 119.34 ft 33.40 - 33.00 ft NAVD88 29.66 – 31.12 ft NAVD88	Modeled as lateral weir; Weir Coefficient (Cd) = 4.0
Fish screen: Width Length Screen top elevation Screen bottom elevation Screen equivalent open area Channel thalweg elevation at structure	1468.96	4.0 ft 44.6 ft 35.0 ft NAVD88 31.0 ft NAVD88 40% 28.57 - 29.64 ft NAVD88	Modeled as lateral weir with single open, square culvert: entrance/exit losses = 0.7 / 1.0; n = 0.08
Water control structure (WCS): Opening width Channel thalweg elevation at structure	1421.32	2.4 ft 28.9 ft NAVD88	Located at head of elevated canal; modeled as inline weir; Weir Coefficient (Cd) = 2.6

- *Notes:*
- *US = upstream*
- *DS = downstream*

Lateral Overflows with Storage Areas
The existing conditions geometry utilizes two lateral overflow structures with storage areas to simulate flow leaving the channel and filling floodplain depressions during bank overtopping events. These are located:

- East of the creek and upstream of SR 14 in the USFWS field, and
- West of the creek and upstream of SR 14 in the Gibbons Creek Mobile Estate (GCME) property.

Lateral structures with storage areas represent the natural topography of the creek's alluvial fan, which is very large and extends both upstream and downstream of the model bounds. The storage areas were created from topographic data (LiDAR, photogrammetry, topographic survey, or a combination of these) to reflect storage volume variations with elevation. The weir elevations were defined from the surveyed tops of the banks of the creek.

Currently, under steady state model simulations, the storage areas do not significantly affect model results because flows into the storage areas necessarily come into equilibrium as the duration of the peak flow storms is assumed to infinite. Steady state simulations thus result in conservative (high) estimates of water levels. Inclusion of the storage areas in the model were done in part to facilitate simulation of unsteady flow hydrographs if it is determined that this future refinement is warranted.

The proposed conditions geometry also has a later overflow with storage area east of the creek representing the USFWS field. However, it does not have the west storage area along the GCME because the floodwall and berm eliminate creek flooding in this area, as described in Section 4.3 below.

3.3. Roughness Coefficients

Manning's roughness coefficients were varied horizontally along each cross section to represent vegetation and bed/bank material variations in the main flow channel, banks, overbank and floodplain, and other areas such as roads and housing developments. Coefficient values were determined through site observations, literature recommendations, modeling experience, and calibration described in Section 4. A summary of roughness coefficient values used in the model is shown in Table 4.

Table 4 Manning's Roughness Coefficient Values Used in the Hydraulic Model.

Gibbons Creek Reach Location	LOB n Value	Description	Channel n Value	Description	ROB n Value	Description	Floodplain n Value	Description	Reference
North of Hwy 14	0.07	Riparian corridor, trees and shrubs	0.03 to 0.035	Gibbons channel, rounded gravels and small cobbles, sparse or no vegetation	0.07	Riparian corridor, trees and shrubs	0.033 0.065	Floodplain field, medium grass Mobile home park	Chow (1959) and field photographs
Diversion Structure Vicinity	0.035	Field, tall grass	0.03 0.02	Gibbons channel, rounded gravels and small cobbles Former gated weir/in-line concrete flume structure	0.035	Field, tall grass	0.035	Floodplain field, tall grass	Chow (1959) and field photographs
Elevated Canal	0.035	Field, tall grass	0.027	Gibbons elevated canal, excavated straight uniform earthen channel with grass	0.035	Field, tall grass	0.035	Floodplain field, tall grass	Chow (1959) and field photographs

Notes:
LOB – left overbank
ROB – right overbank

3.4. Proposed Conditions Geometry

Proposed or restored conditions in the HEC-RAS model are intended to reflect creek restoration actions, including flood risk reduction measures (floodwall and berm) and removal of the existing diversion structures.

The following restoration changes are reflected in the model:

- Upstream of SR 14
  - Realignment and widening of Gibbons Creek through shifting the alignment up to 70 feet east to accommodate a floodwall / earthen berm between the creek and the adjacent GCME and private property on the west bank.
  - The east bank of the creek is laid back and a shallow floodplain bench is designed on this bank (towards the USFWS field) to provide a greater flow area and reduce water levels.
  - The floodwall / berm is a continuation of the west levee until it reaches high ground along the creek.
- At (below) the SR 14 Bridge
  - Restoration of the creek cross section and profile.
  - Return the channel to the approximate conditions that existed prior to the diversion structure, through lowering the thalweg slightly, and widening the channel.
  - Improve conveyance capacity of the channel below the bridge.
  - Provide for hydraulic and sediment transport continuity upstream, below, and downstream of the bridge through gradual transitions in the longitudinal slope of the thalweg.
- Downstream of SR 14
  - Removal of the diversion structure (overflow apron, fish screen, water control structure, elevated canal).
  - Restoration of the creek within its historic alluvial fan.
  - Direct the channel away from the west levee, and grading the floodplain slightly upward in the direction of the levee (to the west) to reduce scour potential along the toe of the levee.
  - Generally follow the alluvial fan topography (which has a gradually decreasing slope towards the wetland) to encourage sediment deposition appropriately far from SR 14 and the levee.

The proposed conditions geometry is based on the existing conditions geometry topography data as described in Section 3.1, with the exceptions noted above. The HEC-RAS model geometry schematic representing proposed (restored) conditions is shown in Figure 8**.**

3.5. Boundary Conditions

The upstream flow boundary conditions in the hydraulic model were defined by the Gibbons Creek flows listed in Table 1. Downstream stage boundary conditions were defined by Columbia River stages described in Section 2.2.

For the existing conditions scenarios, a normal depth boundary condition was applied to the elevated canal. The canal slope used for this boundary condition was 0.0005 (0.05%) as determined through calibration and from canal design information. This boundary condition slope did not vary by flow profile (Gibbons Creek flows) as canal flows did not exceed approximately 80 cfs, which is the capacity of the canal.

3.6. Observed Calibration Data

To calibrate and verify the hydraulic model, two water level gages were installed along Gibbons Creek. The locations of the gages (GC-1 and GC-2) are shown in Figure 2. On September 8, 2015, ESA staff installed GC-2 in the creek immediately downstream of the elevated canal water control gate. The station consists of a 10-foot long section of ABS plastic pipe housing, containing a Solinst Level logger sensor. ESA staff attached the housing pipe to the concrete wall on the left bank wall. A Solinst Barologger was also installed inside the housing to collect barometric pressure data used for atmospheric pressure correction of the water level readings.
On October 9, 2015, ESA staff installed a second gage in Gibbons Creek, approximately 400 feet upstream of the SR 14 Bridge. This station, GC-1, consists of a 10-foot long section of ABS plastic pipe housing, fixed to the bank using rebar staples, steel wire, and steel fence posts. A Solinst Levelogger sensor was installed inside the housing.

Though not used in the Gibbons Creek hydraulic analysis, two additional gages were installed in the Columbia River on September 16, 2015 (see Figure 2). CR-1 was installed along the bank of the Columbia River near River Mile 126.8. CR-1 consists of a 30-foot length of ABS plastic pipe housing, fixed to the bank using rebar staples and steel wire. The bank in this location is armored with rip rap, and some smaller stones were shifted to facilitate placement and attachment of the plastic housing pipe. Once the housing was fixed to the bank, smaller rip rap stones were placed next to and on top of the housing pipe to provide additional ballast. CR-2 was installed on a wooden pile in the Columbia River near Steamboat Landing at RM 125.2. CR-2 consists of a 10-foot long section of ABS plastic pipe housing fixed to the wooden pile using brackets and lag screws.

All loggers were programmed to collect readings of water temperature and water level (via hydrostatic pressure) every 30 minutes. After each station was installed, the team surveyed the elevation of the water surface at the station location. The time of the survey measurement corresponded to the nearest half hour, at a time when the Levelogger would be collecting a water depth reading. This survey data is used to calculate the water surface elevation of each water depth record. The stations began collecting data with the late summer/autumn 2015 low-flow conditions and are continuing to collect data through the spring 2016 runoff season.

Spot measurements of water surface elevation and flow were also taken in December of 2015. The 11/25/15 flow was estimated to be 54 cfs using the Washougal River (Hathaway Park) 15-minute instantaneous gage data scaled by the Gibbons Creek/ Washougal River watershed area ratio. The 12/9/2015 flow was estimated to be 705 cfs based on field measurements of velocity and depths and approximations of cross section area. This flow was also estimated using the Washougal River gage data, and the two flow estimates match within 10 percent. A summary of the spot measurements and continuously recording water surface elevation data in Gibbons Creek is shown in Table 5.

Table 5 Summary of Observed Water Level and Flow Estimate Data.

Nearest River Station	Downstream Distance (ft)	11/25/15 Water Surface Elevation (ft NAVD88)	12/9/2015 Water Surface Elevation (ft NAVD88)	Notes / Location
2093.24	17.0	36.67	37.69	400' US of SR 14; location of GC-1
1697.23	8.9	--	34.72	US face of SR 14 Bridge
1608.08	18.8	--	33.93	Between SR 14 Bridge and lateral overflow apron
1469.73	2.6	--	33.66	US end of fish screen
1422.53	0	--	33.80	US of WCS stoplog guides
1419.54	0	--	33.01	DS of WCS stoplog guides
1403.43	1.7	31.75	33.04	Approx. 15' DS of WCS; location of GC-2

4. Results

4.1. Scenario Summary

The following table summarizes the scenarios developed to evaluate hydraulic conditions in the creek. The scenarios were developed to demonstrate model calibration, changes under proposed conditions, critical water level conditions relevant to floodwall design, and expected future conditions under climate change.

Detailed modeling output tables for all scenarios are included in Appendix B, and cross section plots for existing and proposed model geometries are included in Appendix C.

Table 6 HEC-RAS Scenario Log Summary.

Scenario Name	Model Geometry	Boundary Conditions Columbia R. Stage - Downstream Boundary Condition (Ft. NAVD88)	Boundary Conditions Gibbons Creek Flow - Upstream Boundary Condition (cfs)	Purpose / Notes
Calibration scenarios				Existing conditions model calibration
Low flow	Gibbons Existing	Normal depth (in canal)	54	Observed flow/water level Nov. 25, 2015
High flow	Gibbons Existing	Normal depth (in canal)	705	Observed flow/water level Dec. 9, 2015
Existing versus proposed				Evaluate changes under restoration conditions
Existing conditions	Gibbons Existing	Normal depth (in canal)	(2-yr to 500-yr flows)	Focus on creek hydraulics US of SR 14
Proposed conditions	Gibbons Proposed	Normal depth (in restored creek)	(2-yr to 500-yr flows)	Assumes non-Columbia R. backwatered conditions
Combined 500-Year Probability Scenarios				Determine governing water levels for floodwall / berm design for various 500-year combined probability events (proposed conditions only)
High Columbia stage	Gibbons Proposed	(500-yr) EL. 38.5	(1.01-yr) 200	Extreme Columbia R. stages
Intermediate stage/ Intermediate flow 1	Gibbons Proposed	(100-yr) EL. 35.1	(5-yr) 530	Intermediate Columbia R./creek conditions

Scenario Name	Model Geometry	Boundary Conditions Columbia R. Stage - Downstream Boundary Condition (Ft. NAVD88)	Gibbons Creek Flow - Upstream Boundary Condition (cfs)	Purpose / Notes
Intermediate stage/ intermediate flow 2	Gibbons Proposed	(5-yr) EL. 28	(100-yr) 1,140	Intermediate Columbia R./creek conditions
High Gibbons Creek flow	Gibbons Proposed	(1.01-yr) EL 18.0	(500-yr) 1,470	Extreme Gibbons Creek flows
Climate Change				Evaluate increased flood hydrology effects under existing and proposed conditions, and determine improved resiliency with project conditions
Existing conditions - 2015	Gibbons Existing	Normal depth (in canal)	(2-yr to 500-yr) 2015 flows	Current creek hydrology, without project conditions
Existing conditions - 2080	Gibbons Existing	Normal depth (in canal)	(2-yr to 500-yr) 2080 flows	Future without project
Proposed conditions - 2015	Gibbons Proposed	Normal depth (in restored creek)	(2-yr to 500-yr) 2080 flows	Current with project conditions
Proposed conditions - 2080	Gibbons Proposed	Normal depth (in restored creek)	(2-yr to 500-yr) 2080 flows	Future with project conditions

4.2. Calibration

The purpose of the model calibration was to demonstrate the veracity of the model under low and high flow conditions. The existing conditions HEC-RAS model was run using a 54 cfs low flow (11/25/2015) and a 705 cfs high flow (12/9/15) profile. For these profiles, observed water surface elevations at six locations (upstream of the SR 14 Bridge, between the SR 14 Bridge and the water control structure, and downstream of the water control structure) were used.

Calibration results are displayed in Table 7 and Figure 9. Simulated WSEs match observed water surface elevations within 0.16 feet (0.5% or less difference) at most of the calibration locations. Simulated WSEs at two of the calibration locations (upstream face of the SR 14 Bridge and at the upstream end of the concrete weir abutment wall) were higher than observed WSEs by 1.4 feet (4.0% difference) and 0.6 feet (1.9% difference), respectively. In general simulation and observed WSEs match well, and the calibration is considered good. At the locations near the bridge and upstream end of the overflow weir, the somewhat higher simulated WSEs might be considered conservative with respect to flood risk evaluations.

Table 7 Results of Low and High Flow Model Calibration Scenarios.

River Station	Distance DS from River Station (ft)	Flow (cfs)	Observed WSE (ft NAVD8)	Simulated WSE (ft NAVD88)	Difference in WSE (ft NAVD88)	Percent Diff. in WSE	Location / Notes
Date: 11/25/2015							
1403.43	1.7	54	31.75	31.80	0.05	0.2%	Approx. 15' DS of WCS; location of GC-2
Date: 12/9/15							
1697.23	8.9	705	34.72	36.10	1.38	4.0%	Upstream face of SR 14 Bridge; used RS 1687.00 results
1608.08	18.8	705	33.93	34.57	0.64	1.9%	Upstream of concrete overflow weir abutment wall*
1469.73	2.6	705	33.66	33.79	0.13	0.4%	Upstream end of fish screen
1422.53	0.0	705	33.80	33.75	-0.05	0.1%	Upstream of WCS stoplog guides
1419.54	0.0	705	33.01	32.87	-0.14	0.4%	Downstream of WCS stoplog guides
1403.43	1.7	705	33.04	32.88	-0.16	0.5%	Approx. 15' DS of WCS; location of GC-2
*This location is two feet upstream of RS 1587.21; used simulated results WSE at 1587.21 in this table.							
WSE - water surface elevation							

4.3. Existing and Proposed Conditions

Existing and proposed conditions were compared under a range of creek flows from the 2-year to the 500-year event to generally characterize how the restoration project will affect the hydraulics of extreme flows in the creek. Results are summarized in Table 8, Figure 10 and Figure 11 (water surface elevation profiles), and Figure 12 through Figure 15 (cross sections). The summary table and figures highlight representative water levels (2-

year, 100-year, and 500-year) at key locations throughout the model: downstream of SR 14, several locations along the floodwall and berm adjacent to the creek, and upstream of the creek restoration.

Table 8 Summary of Existing Versus Proposed Water Levels and Depths Over a Range of Creek Hydrology.

	Existing Conditions		Proposed Conditions			
River Station	WSE (ft NAVD88)	Depth (ft)	WSE (ft NAVD8)	Depth (ft)	Change in WSE (ft)	Location Notes
2-Year Profile						
2615.819	45.05	2.87	45.05	2.87	0.00	Between RR Bridge and upstream end of berm
2461.316	43.16	2.70	42.87	2.12	-0.29	Upstream end of project; upstream end of berm
2350.606	41.56	3.33	41.32	1.82	-0.24	Middle of earthen berm
1944.308	37.17	2.37	36.08	2.07	-1.09	Floodwall between berm and SR 14 Bridge
1761.703	35.59	2.49	33.75	2.03	-1.84	Two cross-sections upstream of SR 14 Bridge
1697.238	34.76	2.49	33.35	2.47	-1.41	Upstream of SR 14 Bridge
1608.088	33.98	2.58	32.09	1.96	-1.89	Downstream of SR 14 Bridge
100-Year Profile						
2615.819	47.85	5.67	47.85	5.67	0.00	(Same locations as above profile)
2461.316	45.93	5.47	44.33	3.58	-1.60	
2350.606	43.95	5.72	42.97	3.47	-0.98	
1944.308	39.32	4.52	37.77	3.76	-1.55	
1761.703	38.25	5.15	37.82	6.10	-0.43	
1697.238	38.44	6.17	37.18	6.30	-1.26	
1608.088	36.34	4.94	34.24	4.11	-2.10	
500-Year Profile						
2615.819	48.49	6.31	48.49	6.31	0.00	(Same locations as above profile)
2461.316	46.52	6.06	44.65	3.90	-1.87	
2350.606	44.46	6.23	43.25	3.75	-1.21	
1944.308	39.76	4.96	38.34	4.33	-1.42	
1761.703	38.85	5.75	38.44	6.72	-0.41	
1697.238	39.08	6.81	37.53	6.65	-1.55	
1608.088	36.79	5.39	34.79	4.66	-2.00	

Flood Water Levels

From Table 8 simulation results show that water surface elevations (WSEs) decrease at all locations in the project reach under restored conditions. The exception to this is upstream of the restoration (RS 2615) where the model shows no change in water levels, as anticipated. The magnitude of the decreased WSEs ranges from 0 to over 2 feet, with the locations of largest decrease being downstream of SR 14 (due to diversion removal) and along the upstream end of the floodwall/berm near the private residence where the restored creek channel and floodplain significantly increase.

These results are compared graphically by profile and cross section in Figure 10 through Figure 15. The cross section plots compare geometries and water levels. As a note, existing and proposed profiles do not overlay one another in the model due to the increased length of the restored Gibbons Creek channel downstream of the SR 14 Bridge and slightly different existing and proposed downstream model extents. Therefore, existing and proposed profiles are plotted separately. Also, downstream of cross section 1608 the existing and proposed model cross sections do not overlap because the existing geometry sections are located in the elevated canal and the proposed geometry cross sections are located in the restored Gibbons Creek channel. The cross section plots are compared at the nearest river station, e.g., RSs 1587 and 1559 in Figure 12.

SR 14 Bridge Capacity and Roadway Overtopping

The Gibbons Creek channel below and downstream of the SR 14 Bridge is prone to sedimentation during storms. Sediment conditions are known to change significantly after storms as well as after sediment dredging episodes. 1971 as-constructed and current channel (October 2015 surveyed) conditions below the SR 14 Bridge are compared in a technical memo describing general risks to SR 14 (ESA 2016). The bridge was designed to convey a 50-year flow (cited as 894 cfs) at a water surface elevation of 33.9 feet NAVD88. The current channel bottom has aggraded over two feet relative to as-constructed conditions due to the diversion structure (see Figure 11, ESA 2016). Deposition after storms can add an additional foot of deposition to the current condition, resulting in three or more feet of sedimentation below the bridge.

The hydraulic model was used to quantify bridge conveyance characteristics. Under proposed conditions, the capacity of the SR 14 Bridge over Gibbons Creek improves significantly. The capacity for debris conveyance improves from a 2-year flow under existing conditions (with 1 foot of clearance) to the 10-year flow with approximately 2 feet of clearance under proposed conditions. Under proposed conditions, the 50- and 100-year flows reach the low chord of the bridge, thus providing no debris conveyance. These results are shown graphically in Figure 10 and Figure 11. As a note, the low chord and bridge deck elevations are 36.1 feet NAVD88 and 38.2 feet NAVD88, respectively; the cross section upstream of the bridge listed in Table 8 is RS 1697.

The SR 14 Bridge and roadway is estimated to begin overtopping between the 50- to 100-year flows under existing conditions. Under restored conditions, overtopping is eliminated for all flows including the 500-year event, though the 500-year WSE exceeds the upstream low chord elevation. At the upstream internal bridge cross section the simulated 500-year water levels is 37.53 feet NAVD88, 0.62 feet below the bridge deck elevation of 38.15 feet NAVD88 and 1.43 feet above the low chord elevation of 36.10 feet NAVD88.

Adjacent Property Flooding

Adjacent property flooding on the GCME property west of the creek is estimated to occur between the 50- and 100-year events under existing conditions. Low spots along the existing bank are located at RS 1944 and immediately upstream of SR 14 at RS 1761. These two overtopping locations are shown in Figure 10 (the river right bank lateral overflow to the GCME property is shown behind the left bank lateral overflow). Flooding of the GCME is most sensitive to changes in bed elevation, slope, and capacity of the SR 14 Bridge. Flooding would occur much more frequently if sediments in the diversion structure channel were not dredged regularly. Impacts of potential bed elevation changes were not analyzed as part of this hydraulic analysis.

Under restored conditions (Figure 11), this property is protected under all hydrologic conditions analyzed due to the levee and berm (shown in cross section plots in Figure 12 through Figure 15). The levee and berm crest elevations are 45.6 feet NAVD88, well above the 500-year WSE. Maintenance dredging is no longer anticipated to be required under proposed conditions, as described in Section 3.4.

4.4. Combined 500-Year Frequency Water Levels

Under proposed conditions, 500-year combined frequency conditions were analyzed to determine governing conditions for design of the crest elevation, seepage conditions, and other details of the floodwall and berm along the creek. The four river stage / creek flow scenarios are described in Section 4.1. Results are summarized in Table 9, Figure 16 (profile plot), and Figure 17 and Figure 18 (cross section plots).

From Table 9, upstream of SR 14 (RS 1761), the governing (highest) WSE profile for design of the floodwall and berm is the “WS 500-Year” profile, which corresponds to the 1.01-year Columbia stage / 500-year Gibbons flow. Downstream of SR 14, the governing WSE profile for design of the levee is the “WS 1.01-Year” profile, which corresponds to the 500-year Columbia stage / 1.01-year Gibbons flow.

Levee/Berm Freeboard

The levee and berm freeboard is reported for each profile and at representative locations in Table 9. The freeboard is well above 3 feet downstream of SR 14 and in the middle sections of the floodwall upstream of SR14, with the exception of the middle and upstream ends of the berm (see RSs 2350 and 2461 at the bottom of the table under the 500-year Gibbons flow profile). The relative freeboard at these locations is also shown in Figure 18. The freeboard at these locations for the 500-year Gibbons flow is 2.45 and 1.05 feet, respectively. The WSEs at these two cross sections is also below the ground surface on the landward side of the berm as shown in the cross section figures. Thus the actual risk off impacts from 100-year Gibbons Creek flows with or without the berm does not appear to be significant, though the FEMA freeboard criterion of 3 feet relative to the base flood event is not strictly met at these locations. Regardless, it is likely possible to provide adequate FEMA freeboard through small increases in the berm elevation and extents, and/or possibly through further design refinements of the restored channel.

Table 9 Summary of Hydraulic Conditions Under 500-Year Combined Frequency Scenarios

River Station	Flow (cfs)	WSE (ft NAVD88)	Depth (ft)	Free-board (ft)	Velocity (ft/s)	Location Notes
500-Yr Columbia Stage + 1.01-Yr Gibbons Flow						
2615.819	200	44.38	2.20	N/A	4.48	Between RR Bridge and upstream end of berm
2461.316	200	42.41	1.66	3.29	4.79	Upstream end of project; upstream end of berm
2350.606	200	40.86	1.36	4.84	6.12	Middle of earthen berm
1944.308	200	38.53	4.52	7.17	1.15	Floodwall between berm and SR 14 Bridge
1761.703	194	38.53	6.81	7.17	0.46	Two cross-sections upstream of SR 14 Bridge
1559.700	194	38.50	9.23	7.20	0.34	Two cross-sections downstream of SR 14 Bridge
100-Yr Columbia Stage + 5-Yr Gibbons Flow						
2615.819	530	46.04	3.86	N/A	4.96	(Same locations as above profile)
2461.316	530	43.38	2.63	2.32	6.86	
2350.606	530	42.23	2.73	3.47	6.21	
1944.308	530	36.77	2.76	8.93	7.02	
1761.703	530	35.36	3.64	10.34	4.32	
1559.700	530	35.07	5.80	10.63	2.33	
5-Yr Columbia Stage + 100-Yr Gibbons Flow						
2615.819	1,140	47.85	5.67	N/A	5.70	(Same locations as above profile)
2461.316	1,140	44.33	3.58	1.37	8.21	
2350.606	1,140	42.97	3.47	2.73	7.87	
1944.308	1,140	37.77	3.76	7.93	8.91	
1761.703	1,140	37.82	6.10	7.88	3.33	
1559.700	1,140	33.46	4.19	12.24	8.94	
1.01-Yr Columbia Stage + 500-Yr Gibbons Flow						
2615.819	1,470	48.49	6.31	N/A	6.18	(Same locations as above profile)
2461.316	1,470	44.65	3.90	1.05	9.03	
2350.606	1,470	43.25	3.75	2.45	8.65	
1944.308	1,470	39.01	5.00	6.69	7.24	
1761.703	1,429	39.09	7.37	6.61	2.97	
1559.700	1,429	33.97	4.70	11.73	9.27	

4.5. Climate Change Resiliency

The effects of climate change were evaluated to determine the sensitivity and potentially higher resiliency of the restored creek and flood risk reduction components. Results of climate change scenario simulations are summarized in Table 10 and Table 11, and Figure 19 and Figure 20.

Table 10 Comparison of 2015 and 2080 (Future With Climate Change) Scenarios Under Existing Conditions.

	2015 Hydrology				2080 Hydrology (w/ Climate Change)					
River Station	Flow (cfs)	WSE (ft NAVD88)	Depth (ft)	Velocity (ft/s)	Flow (cfs)	WSE (ft NAVD88)	Depth (ft)	Velocity (ft/s)	Change in WSE (ft)	Location Notes
2-Year Profile										
2615.819	320	45.05	2.87	4.86	380	45.35	3.17	4.92	0.30	Between RR Bridge & US end of berm
2461.316	320	43.16	2.70	4.62	380	43.40	2.65	4.95	0.24	Upstream end of berm
2350.606	320	41.56	3.33	4.45	380	41.81	2.31	4.84	0.25	Middle of earthen berm
1944.308	320	37.17	2.37	7.81	380	37.67	3.66	6.99	0.50	Floodwall between berm and SR 14 Br
1761.703	320	35.59	2.49	6.73	380	35.76	4.04	7.36	0.17	Two cross-sections US of SR 14 Br
1697.238	320	34.76	2.49	7.48	380	35.05	4.17	7.56	0.29	Upstream of SR 14 Bridge
1608.088	320	33.98	2.58	7.58	380	34.23	4.10	7.86	0.25	Downstream of SR 14 Bridge
100-Year Profile										
2615.819	1,140	47.85	5.67	5.70	1,370	48.30	6.12	6.05	0.45	(Same locations as above profile)
2461.316	1,140	45.93	5.47	5.50	1,370	46.35	5.60	5.64	0.42	
2350.606	1,140	43.95	5.72	8.03	1,370	44.55	5.05	8.11	0.60	
1944.308	1,137	39.32	4.52	8.97	1,337	39.66	5.65	9.29	0.34	
1761.703	1,132	38.25	5.15	8.25	1,297	38.72	7.00	8.19	0.47	
1697.238	1,132	38.44	6.17	4.50	1,297	38.94	8.06	4.30	0.50	
1608.088	1,132	36.34	4.94	9.99	1,297	36.68	6.55	10.31	0.34	
500-Year Profile										
2615.819	1,470	48.49	6.31	6.18	1,760	48.98	6.80	6.54	0.49	(Same locations as above profile)
2461.316	1,470	46.52	6.06	5.69	1,760	46.82	6.07	6.13	0.30	
2350.606	1,470	44.46	6.23	8.95	1,760	44.82	5.32	9.54	0.36	
1944.308	1,408	39.76	4.96	9.42	1,576	40.05	6.04	9.54	0.29	
1761.703	1,349	38.85	5.75	8.18	1,462	39.15	7.43	8.17	0.30	
1697.238	1,349	39.08	6.81	4.26	1,462	39.39	8.51	4.17	0.31	
1608.088	1,349	36.79	5.39	10.37	1,462	37.02	6.89	10.51	0.23	

Under existing conditions WSEs in the creek are expected to rise on the order of 0.2 to 0.6 feet due to climate change depending on the flow profile and location. Overtopping the banks of the creek will increase on both sides of the creek (see profile plot in Figure 19). For example, during the 100-year creek flow, the overflow towards the GCME property is expected to increase from less than 5 cfs to over 40 cfs due to the approximate 0.5 foot rise in WSE in this vicinity.

In Table 11 proposed conditions show increases in WSE that are generally similar in magnitude to those under existing conditions. Increases range from 0.2 to 0.5 feet. Note that the simulated change in WSE at RS 1697 (immediately upstream of the SR 14 Bridge) under the 500-year profile shows a negative change. This is believed to be due to the calculated depth defaulting to critical depth for the higher 2080 profile, whereas a subcritical depth solution is found for the 2015 flow profile. This change likely could be resolved by adding interpolated cross sections downstream of this RS and does not appear to otherwise adversely affect simulation results.

2080 Existing and Proposed Conditions Comparison

As described in Section 4.3, the proposed restoration results in decreased WSEs on the order of 0 to over 2 feet, especially downstream of SR 14 and along the upstream end of the floodwall/berm near the private residence. This general result is also true under 2080 future climate change estimates. For example, under the 2080 100-year profile at the upstream end of the berm (RS 2350 – middle of the berm), the existing and proposed WSEs are 44.55 and 43.17 feet NAVD88, respectively. This decrease of 1.38 feet is slightly larger than the 2015 decrease shown in Table 8 of 0.98 feet. For the 500-yr profile at this same location, the 2080 decrease under restored conditions (1.26 feet) is also slightly larger than the respective 2015 decrease (1.21 feet).

In general, the lower water levels in Gibbons Creek resulting from the proposed restoration (0 to 2 feet as described in Section 4.3) will be significant relative to the rises in creek water levels estimated as a result of climate change (on the order of 6 inches). Thus restoration would provide meaningful resiliency to the effects of climate change particularly regarding SR 14 Bridge capacity and overtopping and other properties and infrastructure that are sensitive to flood water levels in the creek.

Table 11 Comparison of 2015 and 2080 (Future With Climate Change) Scenarios Under Proposed Conditions.

	2015 Hydrology				2080 Hydrology (w/ Climate Change)					
River Station	Flow (cfs)	WSE (ft NAVD88)	Depth (ft)	Velocity (ft/s)	Flow (cfs)	WSE (ft NAVD88)	Depth (ft)	Velocity (ft/s)	Change in WSE (ft)	Location Notes
2-Year Profile										
2615.819	320	45.05	2.87	4.86	380	45.35	3.17	4.92	0.30	Between RR Bridge & US end of berm
2461 316	320	42.87	2.41	5.68	380	43.05	2.30	6.03	0.18	Upstream end of berm
2350.606	320	41.32	3.09	6.92	380	41.51	2.01	7.25	0.19	Middle of earthen berm
1944 308	320	36.08	1.28	6.38	380	36.28	2.27	6.71	0.20	Floodwall between berm and SR 14 Br
1761.703	320	33.75	0.65	6.53	380	33.96	2.24	6.86	0.21	Two cross-sections US of SR 14 Br
1697 238	320	33.35	1.08	5.14	380	33.57	2.69	5.53	0.22	Upstream of SR 14 Bridge
1608.088	320	32.09	0.69	6.84	380	32.27	2.14	7.28	0.18	Downstream of SR 14 Bridge
100-Year Profile										
2615.819	1,140	47.85	5.67	5.70	1,370	48.31	6.13	6.04	0.46	(Same locations as above profile)
2461 316	1,140	44.33	3.87	8.21	1,370	44.56	3.81	8.79	0.23	
2350.606	1,140	42.97	4.74	7.87	1,370	43.17	3.67	8.43	0.20	
1944 308	1,140	37.77	2.97	8.91	1,370	38.27	4.26	8.72	0.50	
1761.703	1,140	37.82	4.72	3.32	1,368	38.36	6.64	3.42	0.54	
1697 238	1,140	37.18	4.91	6.05	1,368	37.60	6.72	6.63	0.42	
1608.088	1,140	34.24	2.84	9.03	1,368	34.63	4.50	9.38	0.39	
500-Year Profile										
2615.819	1,470	48.49	6.31	6.18	1,760	48.98	6.80	6.54	0.49	(Same locations as above profile)
2461 316	1,470	44.65	4.19	9.03	1,760	44.90	4.15	9.66	0.25	
2350.606	1,470	43.25	5.02	8.65	1,760	43.56	4.06	9.24	0.31	
1944 308	1,470	38.34	3.54	9.11	1,760	38.56	4.55	10.06	0.22	
1761.703	1,467	38.44	5.34	3.59	1,748	38.71	6.99	3.99	0.27	
1697 238	1,467	37.53	5.26	7.22	1,748	37.04	6.16	9.52	-0.49	
1608.088	1,467	34.79	3.39	9.53	1,748	35.24	5.11	9.71	0.45	

5. Summary of Findings

The following is a summary of the hydraulic analysis presented above:

- A HEC-RAS hydraulic model was developed for Gibbons Creek. The model was calibrated using observed flow and water level data during low and high flow conditions, with simulated and observed water surface elevations matching well at several locations. Percent differences between observed and simulated water surface elevations were generally less than 2 percent.

- Compared to existing conditions, water surface elevations in Gibbons Creek under restored conditions decreased throughout the project reach at all locations and for all flow profiles analyzed. The magnitude of the decreases ranged from several inches to over 2 feet. The reasons for the decreases were removal of the diversion structure and restoration of the creek channel through a larger channel and floodplain area, particularly at the upstream end of the floodwall and berm.

- Under restored conditions, the capacity of the channel below the SR 14 Bridge for conveyance of debris (with at least 1 foot of clearance) improves from approximately the 2-year flow to the 10-year flow. Bridge overtopping is estimated to reduce from the 50- to 100-year flow under existing conditions to non-overtopping under restored conditions including 500-year creek flows.

- Considering a range of 500-year combined frequency Columbia River stages and Gibbons Creek flows, the governing (highest) water surface profile for design of the floodwall and berm (upstream of SR 14) is the 1.01-year Columbia River stage / 500-year Gibbons Creek flow. Downstream of SR 14, the governing water surface profile becomes the 500-year Columbia River stage / 1.01-year Gibbons Creek flow.

- Under restored conditions, the GCME and private properties west of the creek are protected under all hydrologic conditions analyzed including all combined 500-year stage/flow frequencies due to the floodwall and berm (part of the west setback levee system).

- Freeboard on the west setback levee and closure structure is well over 3 feet downstream of SR 14 and in the middle sections of the floodwall (upstream of SR14). However, freeboard in the middle and upstream end of the berm (approximately 1 to 2 feet) along the private property does not meet FEMA's freeboard criterion. However, the water surface elevations at these two cross sections are also below the ground surface landward of the berm. Also, it may be possible to further refine the channel design to decrease water levels and meet the freeboard criterion.

- Under existing (future without project) conditions, water surface elevations in the creek are expected to rise on the order of 0.2 to 0.6 feet due to climate change; proposed conditions show similar though slightly smaller increases. Because creek water surface elevations are anticipated to decrease by this amount or more as part of the restoration, the project is expected to improve the resiliency of infrastructure and adjacent properties to the effects of climate change on flood water levels Gibbons Creek.

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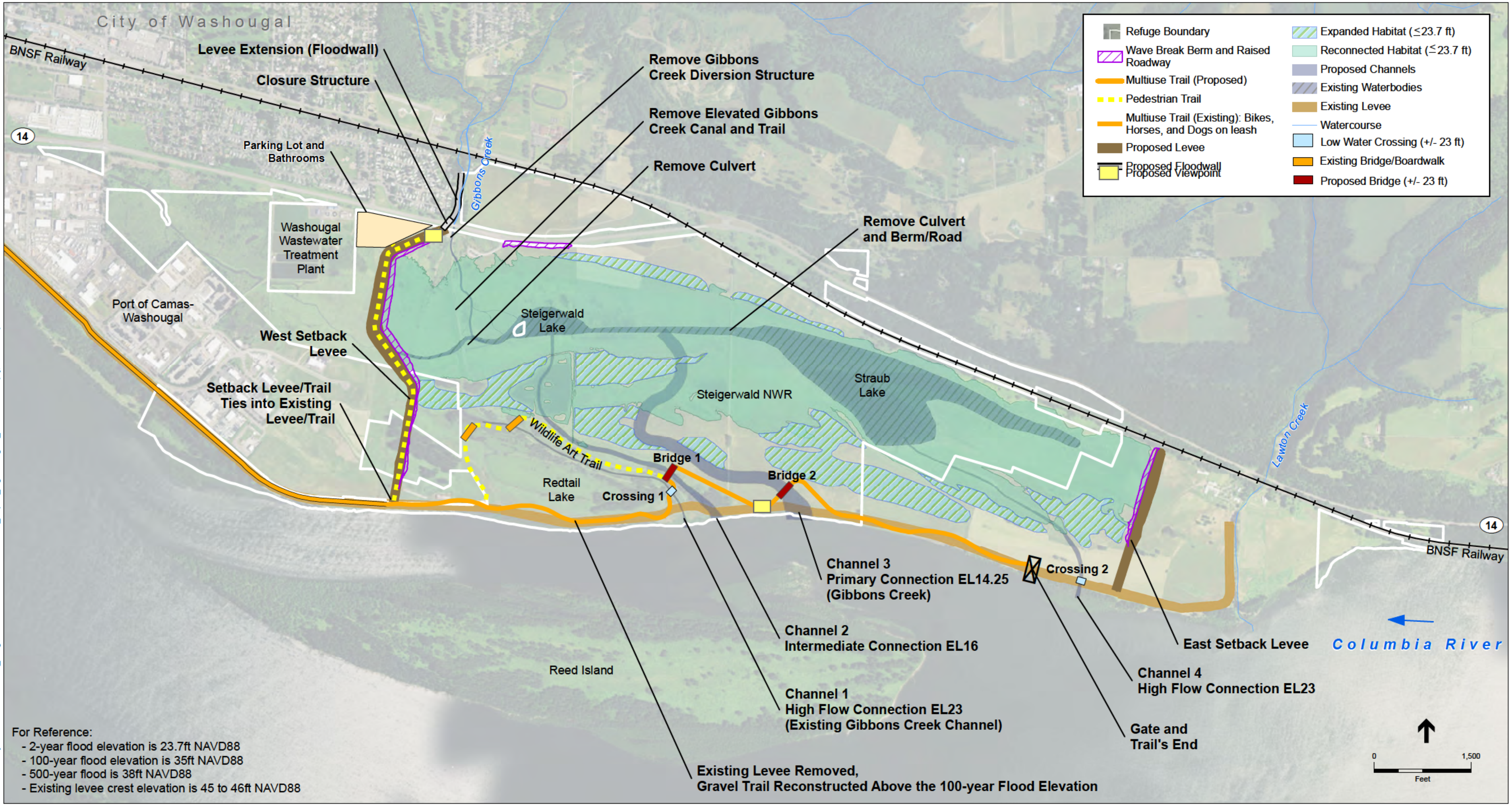
Proposed Conditions - Low Columbia River Stage
Proposed Conditions - High Columbia River Stage

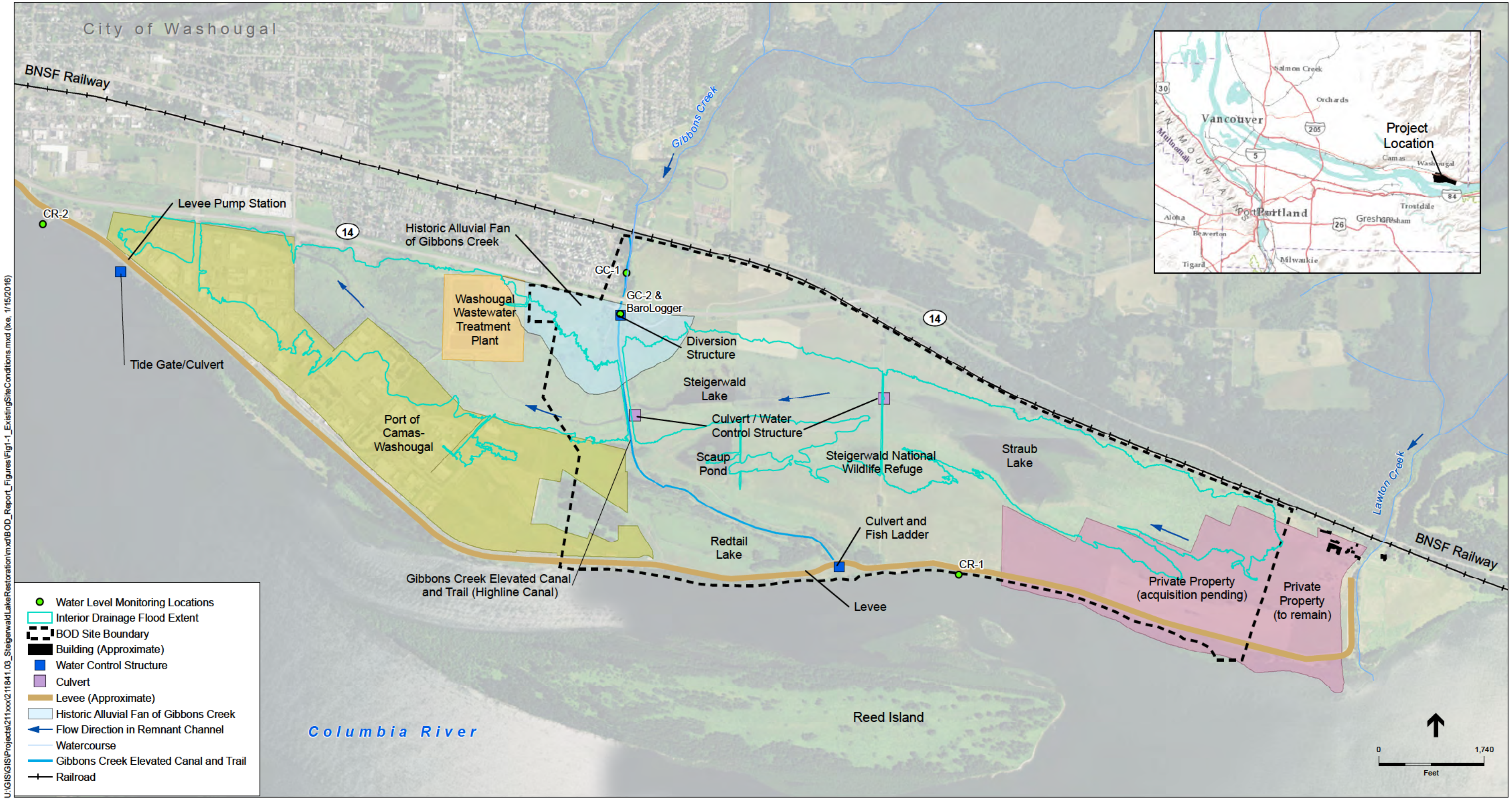
Appendix C
Cross Section Plots

Scenarios:
Existing Conditions
Proposed Conditions - Low Columbia River Stage
Proposed Conditions - High Columbia River Stage



SOURCE: LCEP, 2013; Clark County; National Hydrography Dataset; USACE LiDAR, 2010
Service Layer Credits: ESRI 2013

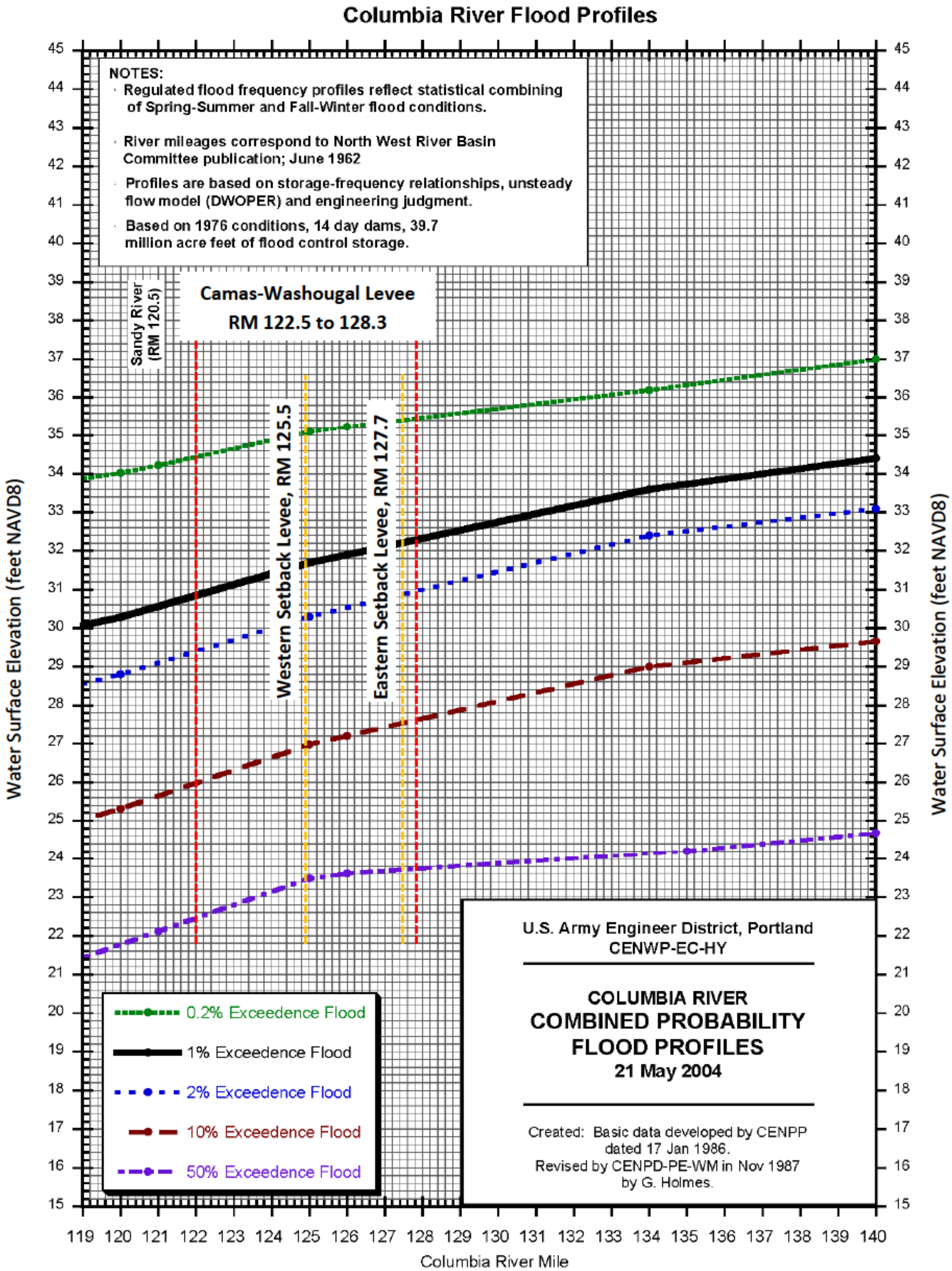
Figure 1
Proposed Floodplain Restoration Overview
Washougal, Washington



SOURCE: LCEP, 2013; Clark County; National Hydrography Dataset; USACE LiDAR, 2010
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Sources: Esri, DeLorme, USGS, NPS
Sources: Esri, USGS, NOAA

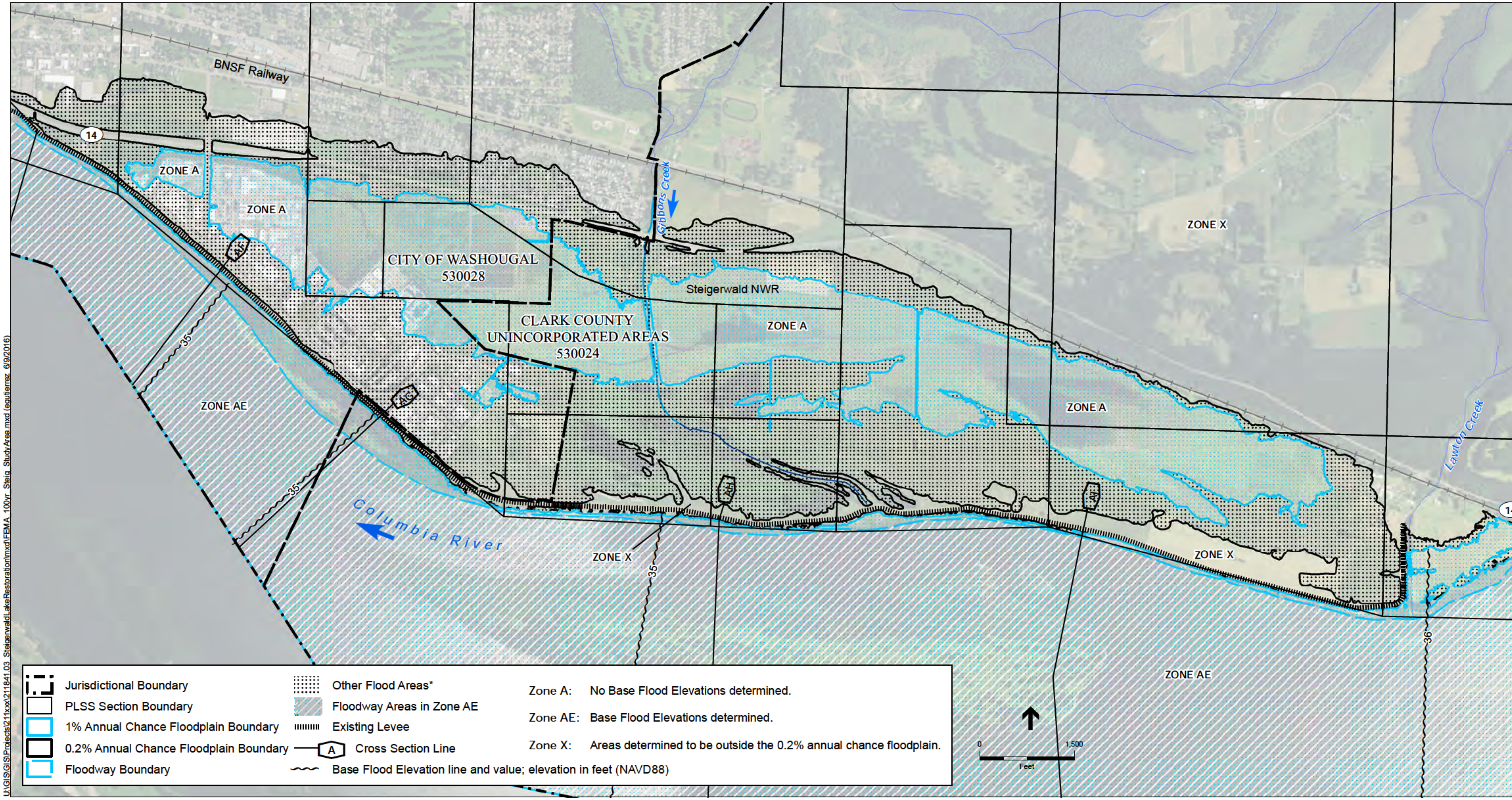
Steigerwald Design . D140746.02

Figure 2
Existing Site Conditions at Steigerwald National Wildlife Refuge
Washougal, Washington



SOURCE: USACE 2007.

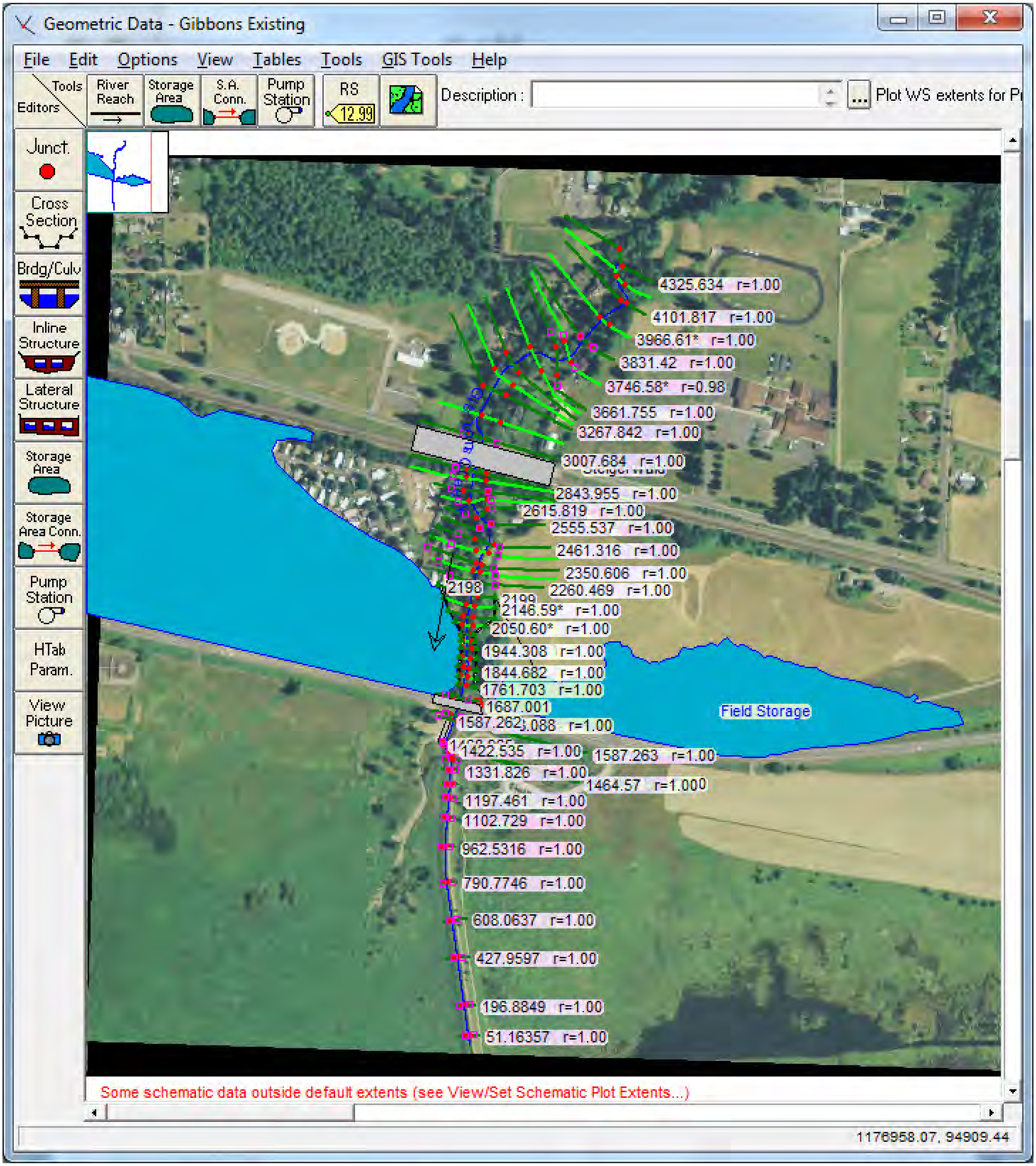
Figure 3
Combined Probability Columbia River Flood Profiles.



SOURCE: LCEP, 2013; Clark County; National Hydrography Dataset; FEMA 2015 (Panels: 0553D, 0554D, 0560D, 0562D, 0570D); NAIP, 2014.

* Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

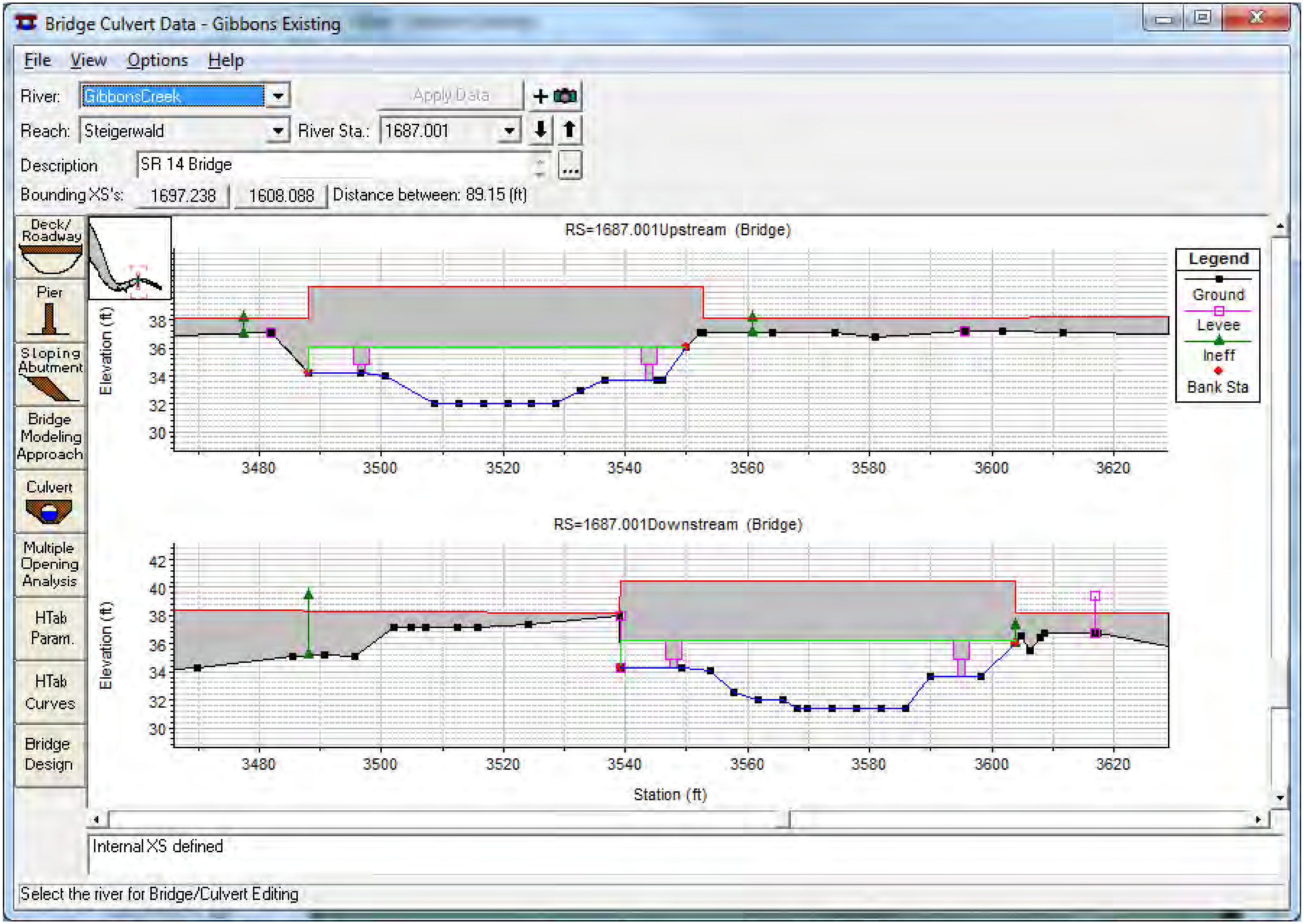
Figure **4**
FEMA Floodplain Map
Washougal, Washington



SOURCE:

Steigerwald Restoration Design . D140746.02

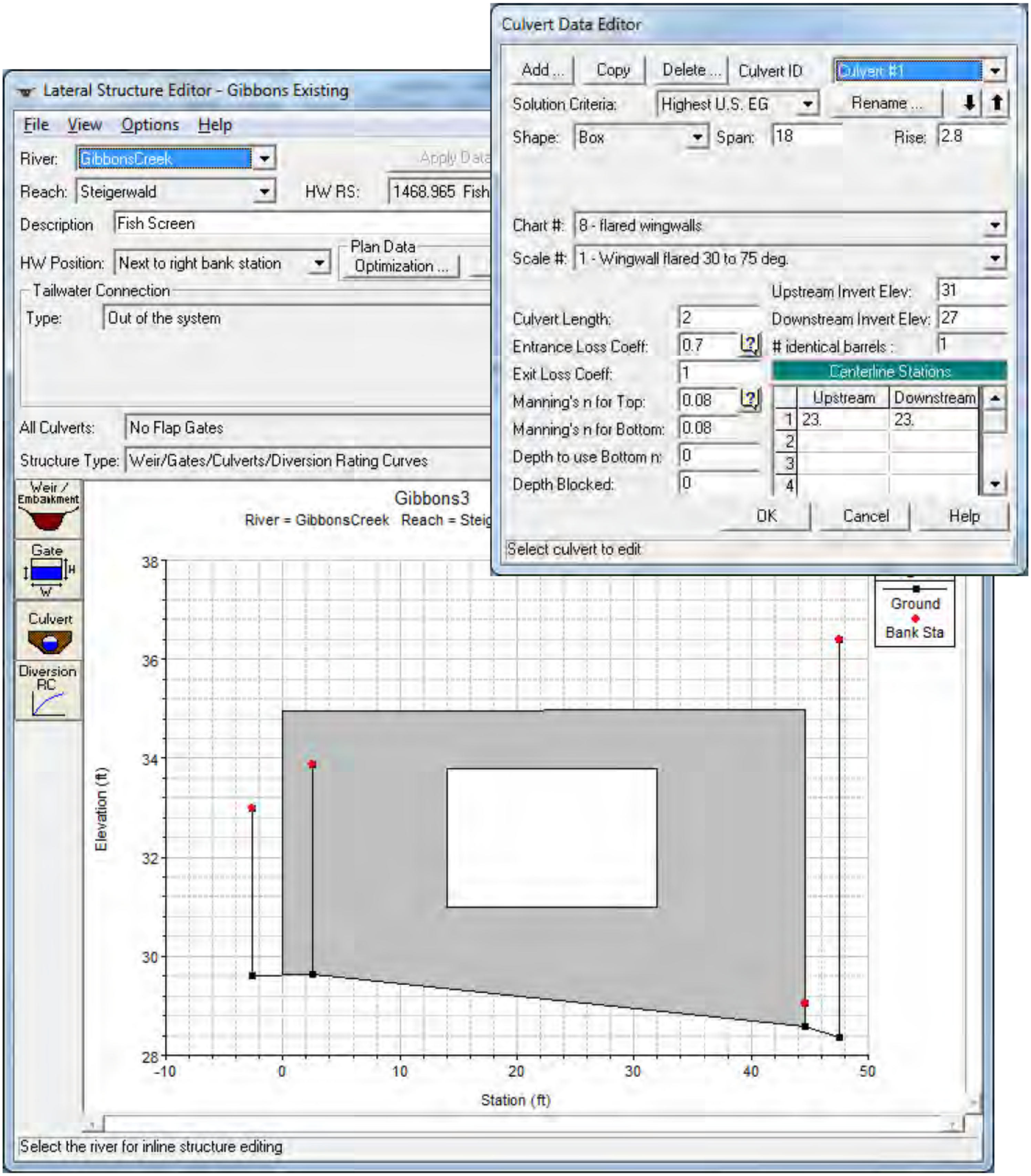
Figure 5
HEC-RAS Geometry Schematic
For Existing Conditions.



SOURCE: Helvetica or Arial Regular 7pt

Steigerwald Restoration Design . D140746.02

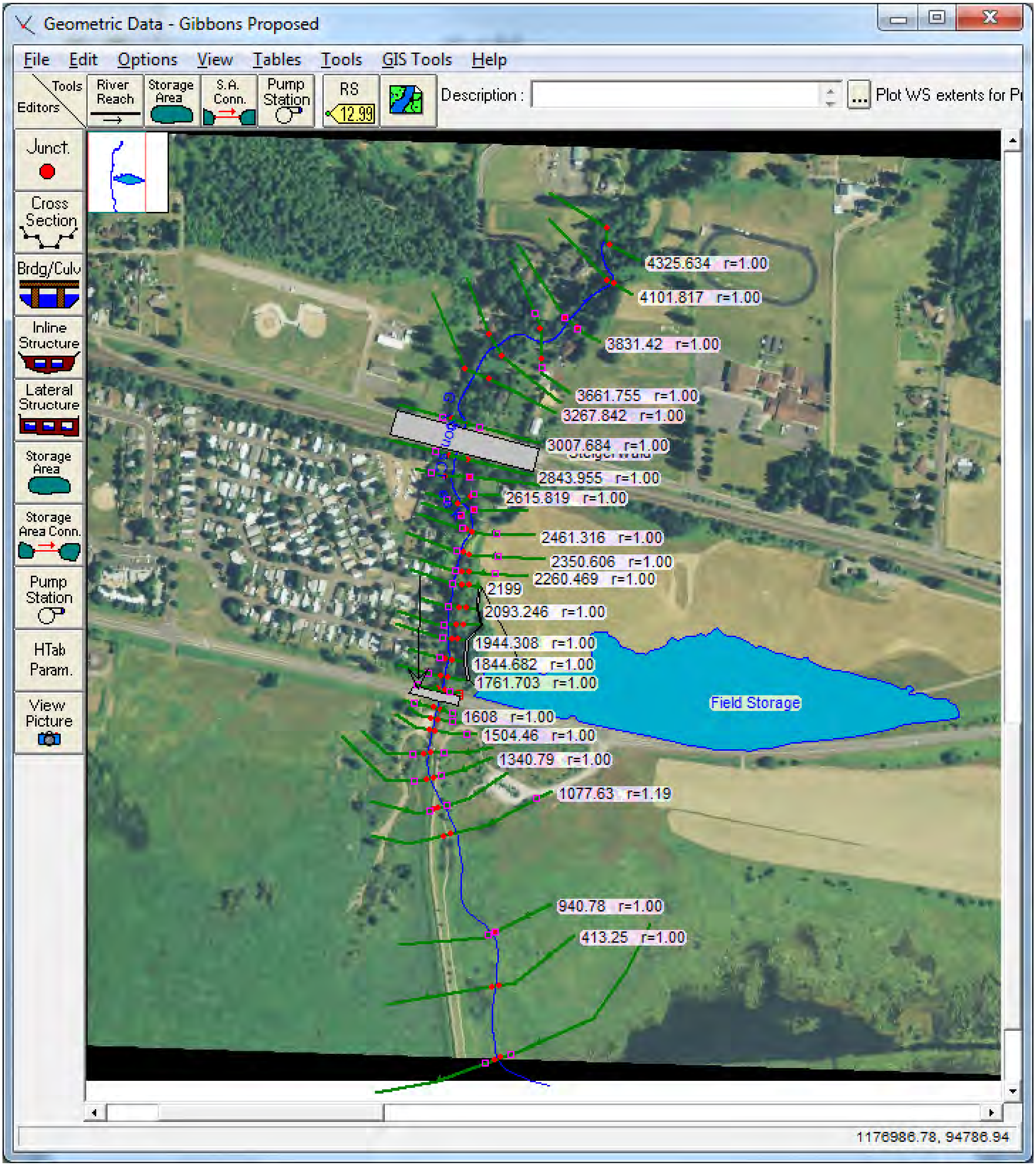
Figure 6
HEC-RAS Geometry Schematic of the
SR 14 Bridge Upstream and Downstream Cross Sections.



SOURCE:

Steigerwald Restoration Design . D140746.02

Figure 7
HEC-RAS Schematic for the Gibbons Creek Fish Screen.



SOURCE:

Steigerwald Restoration Design . D140746.02

Figure 8

HEC-RAS Geometry Schematic
For Proposed Conditions.

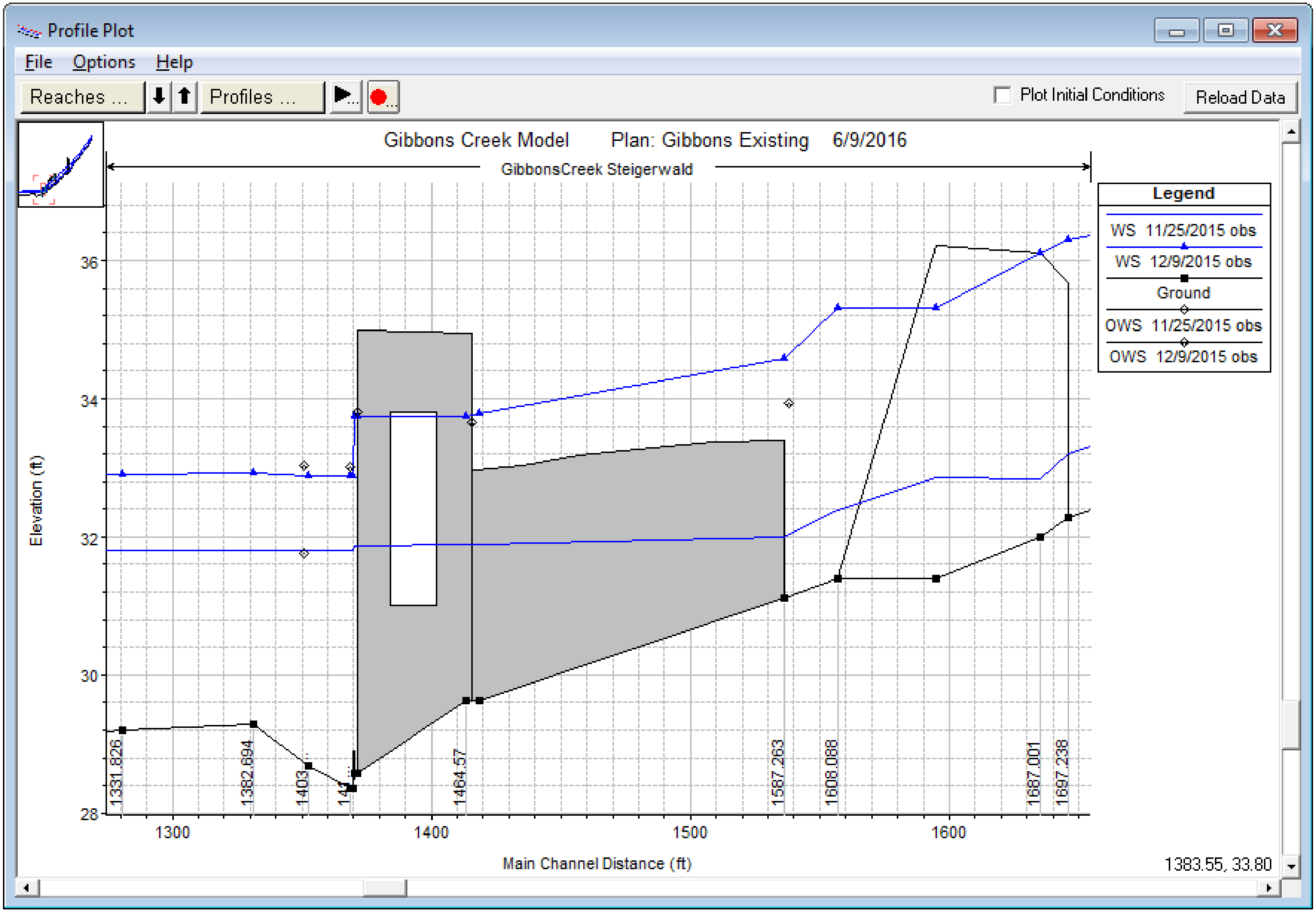


Figure 9
Comparison of Simulated Water Surface Elevation Profile Results
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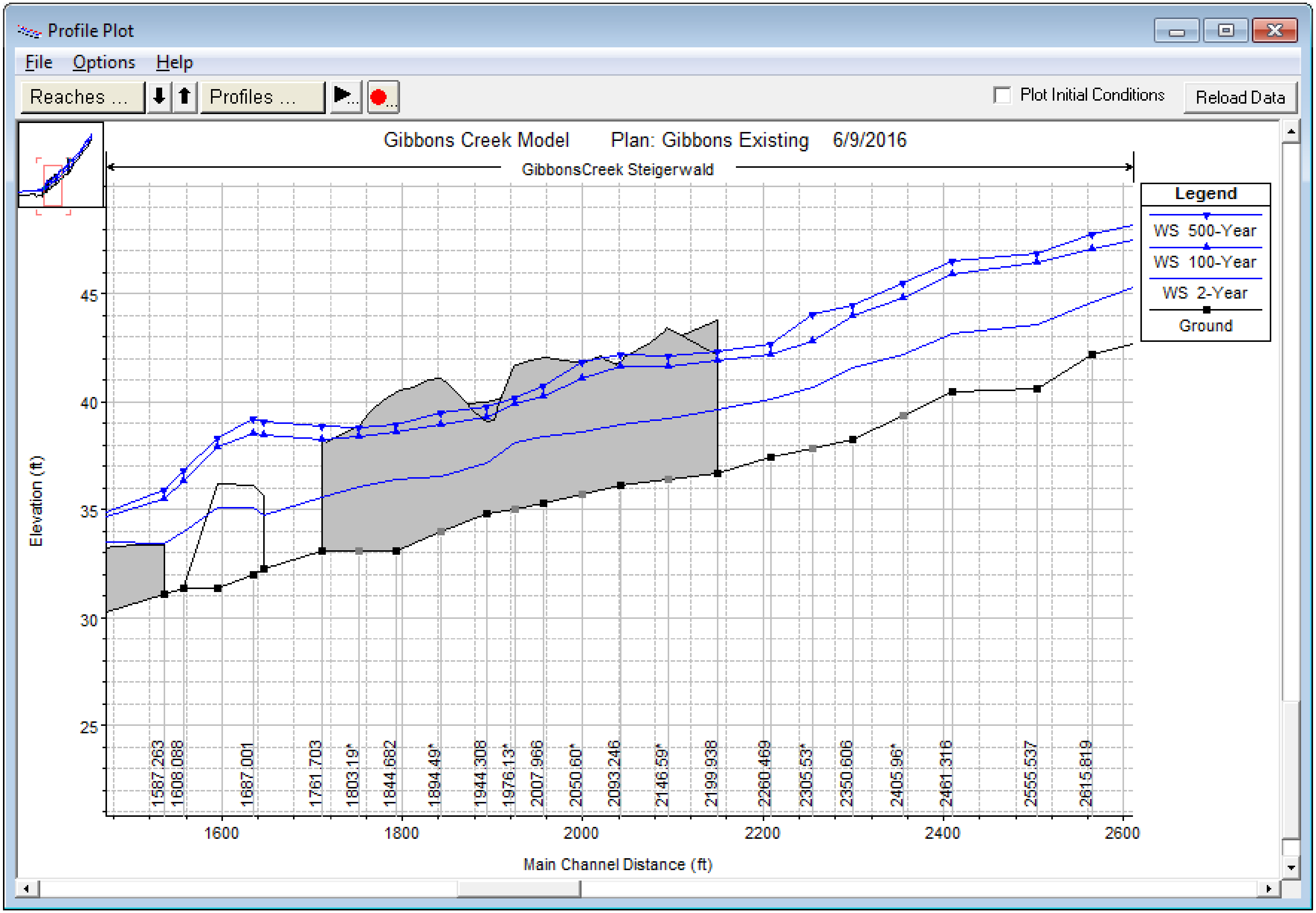


Steigerwald Design . D140746.02

Figure 10

Simulated Water Surface Elevation Profile Results Under Existing Conditions.

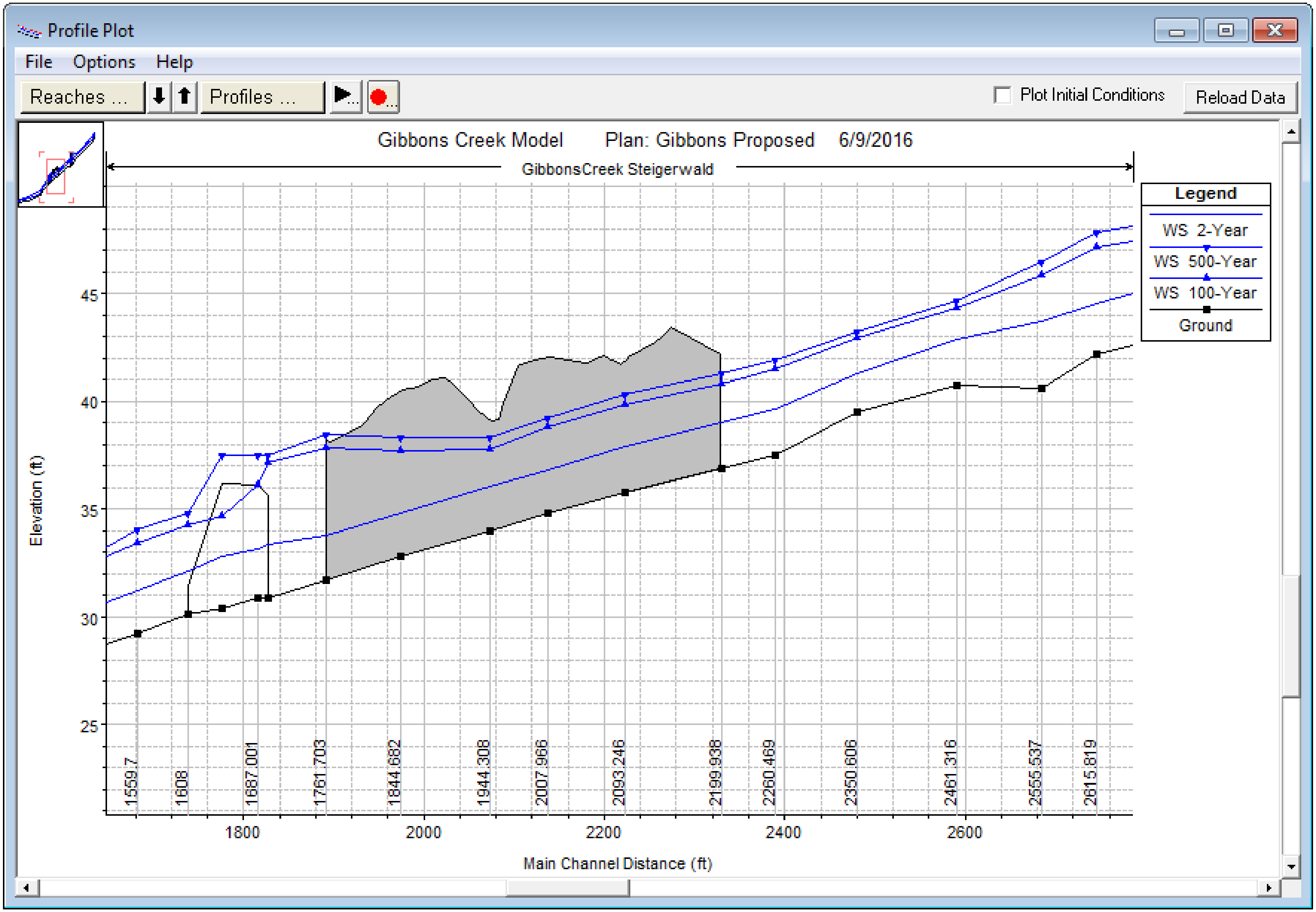
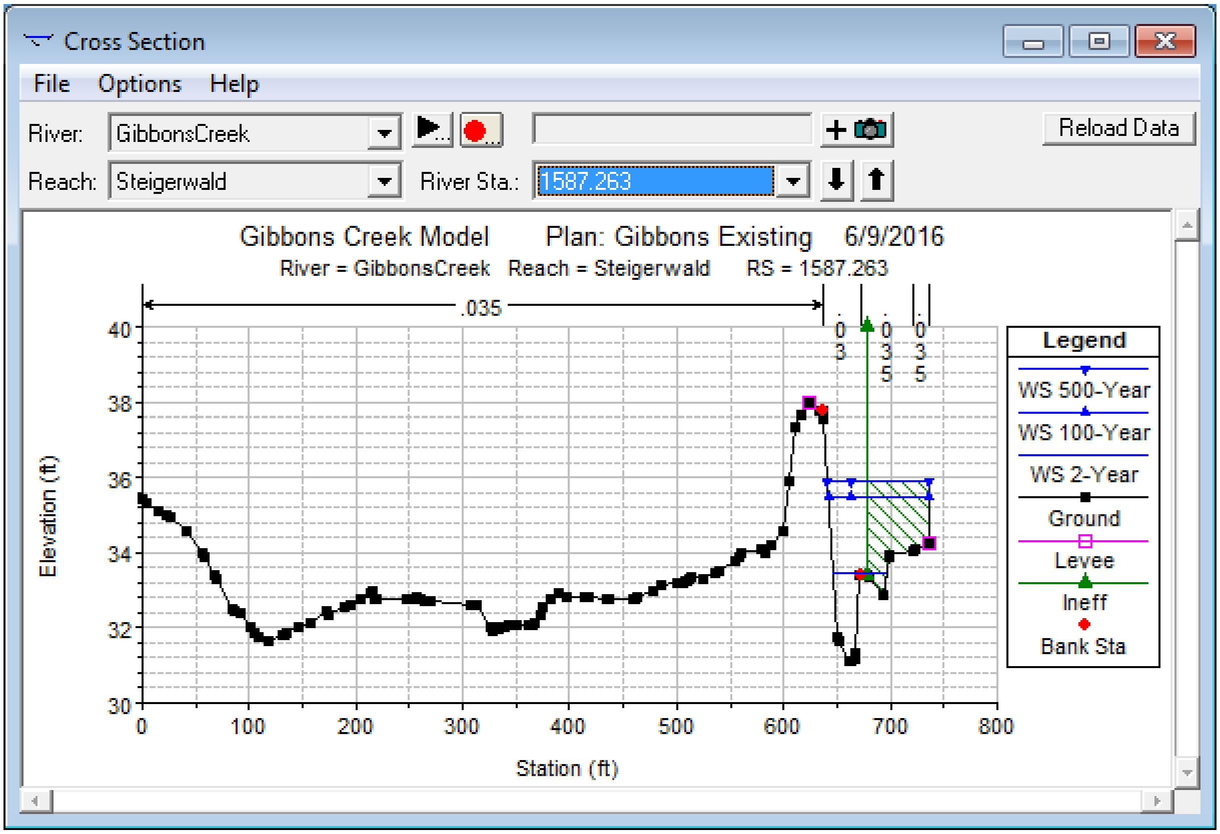
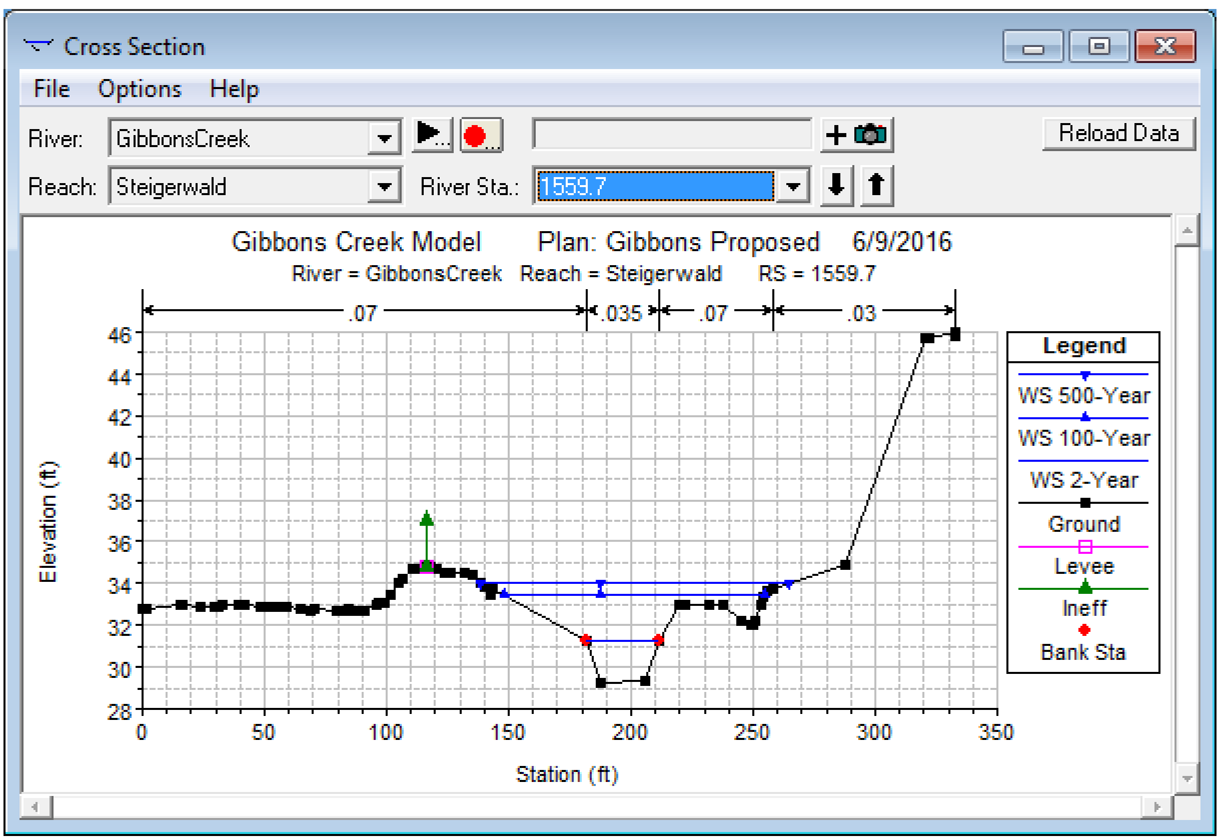


Figure 11
Simulated Water Surface Elevation Profile Results
Under Proposed Conditions.





Note: Existing RS 1587 and Proposed RS 1559 are approximately the same location.

Figure 12
Existing (Top) Versus Proposed (Bottom)
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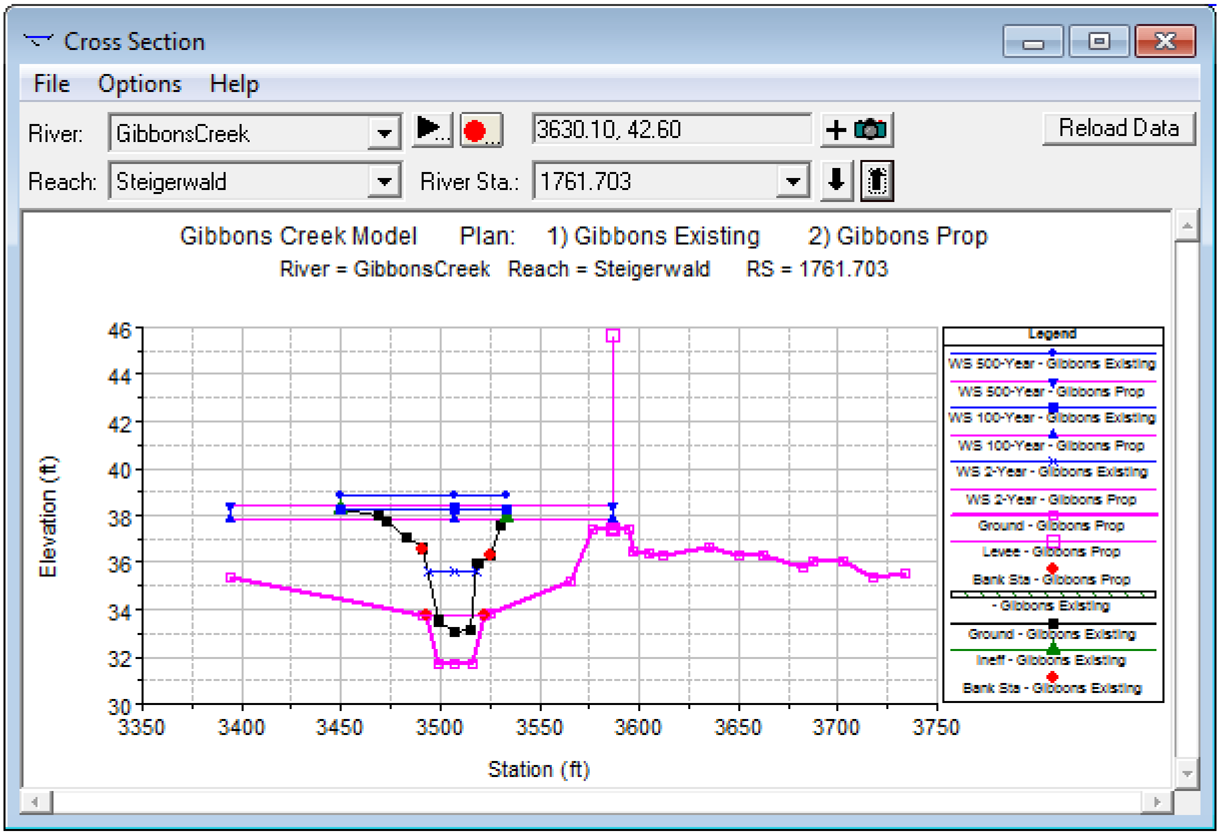

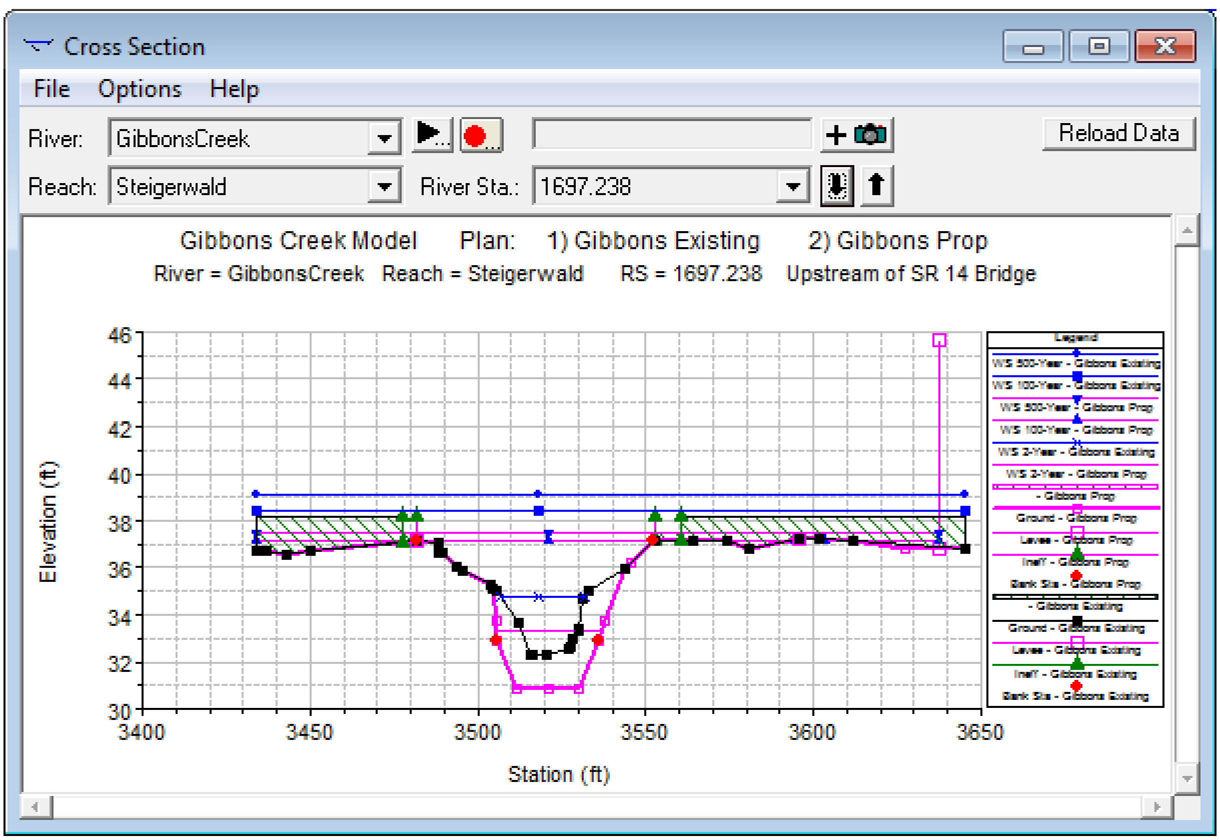

Figure 13
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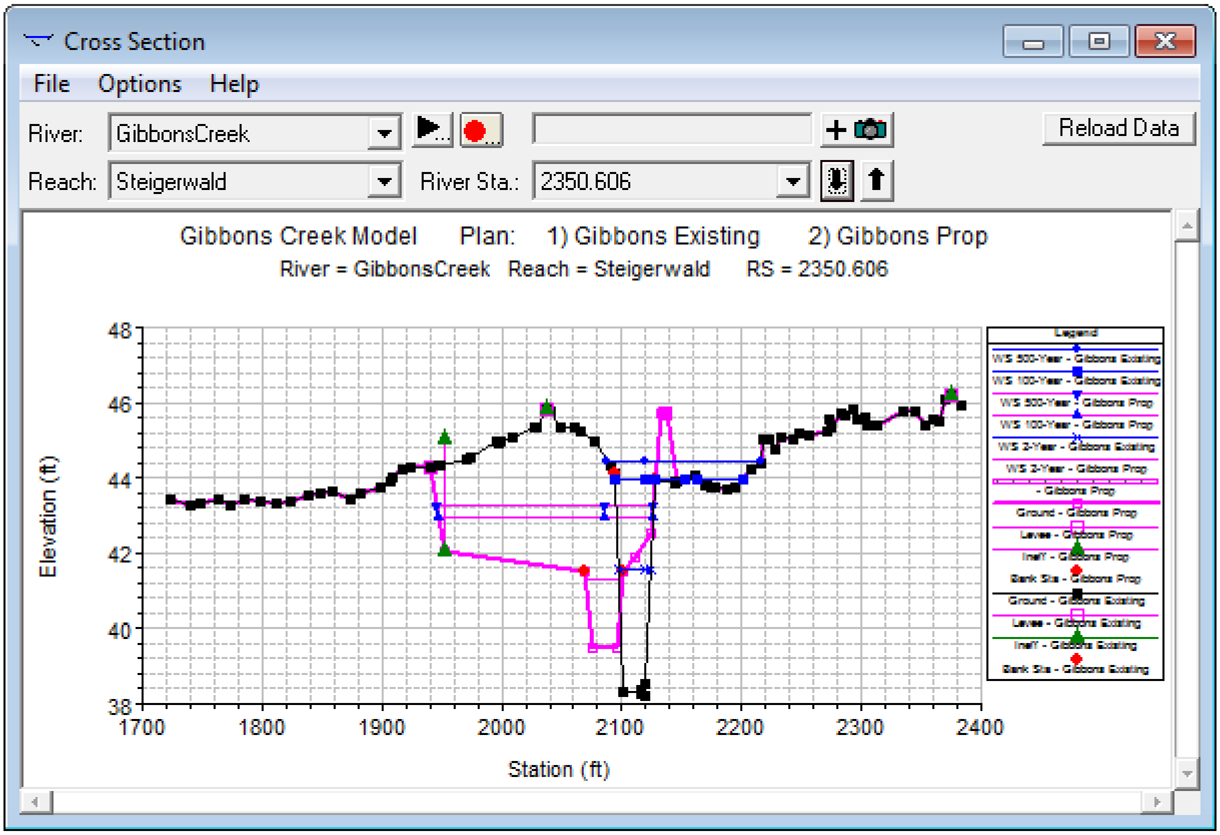

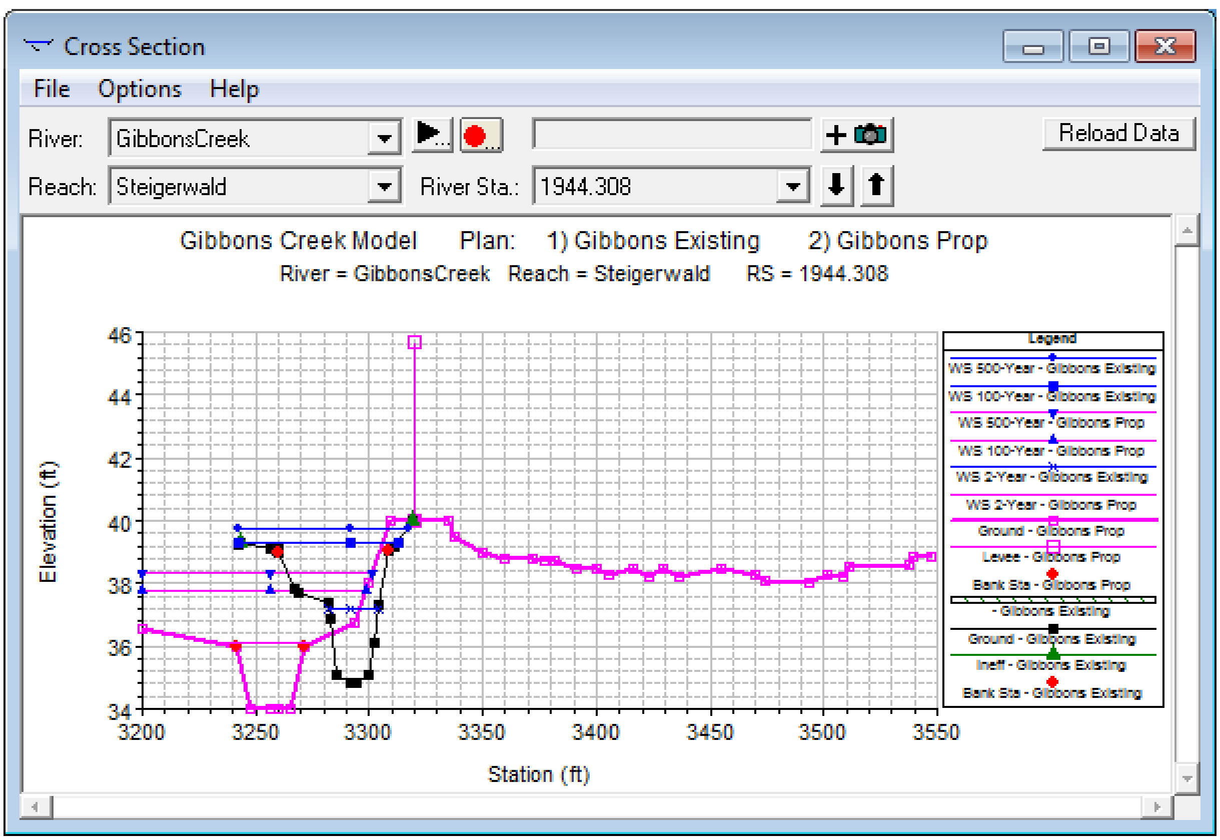

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Existing Versus Proposed Cross Section Results
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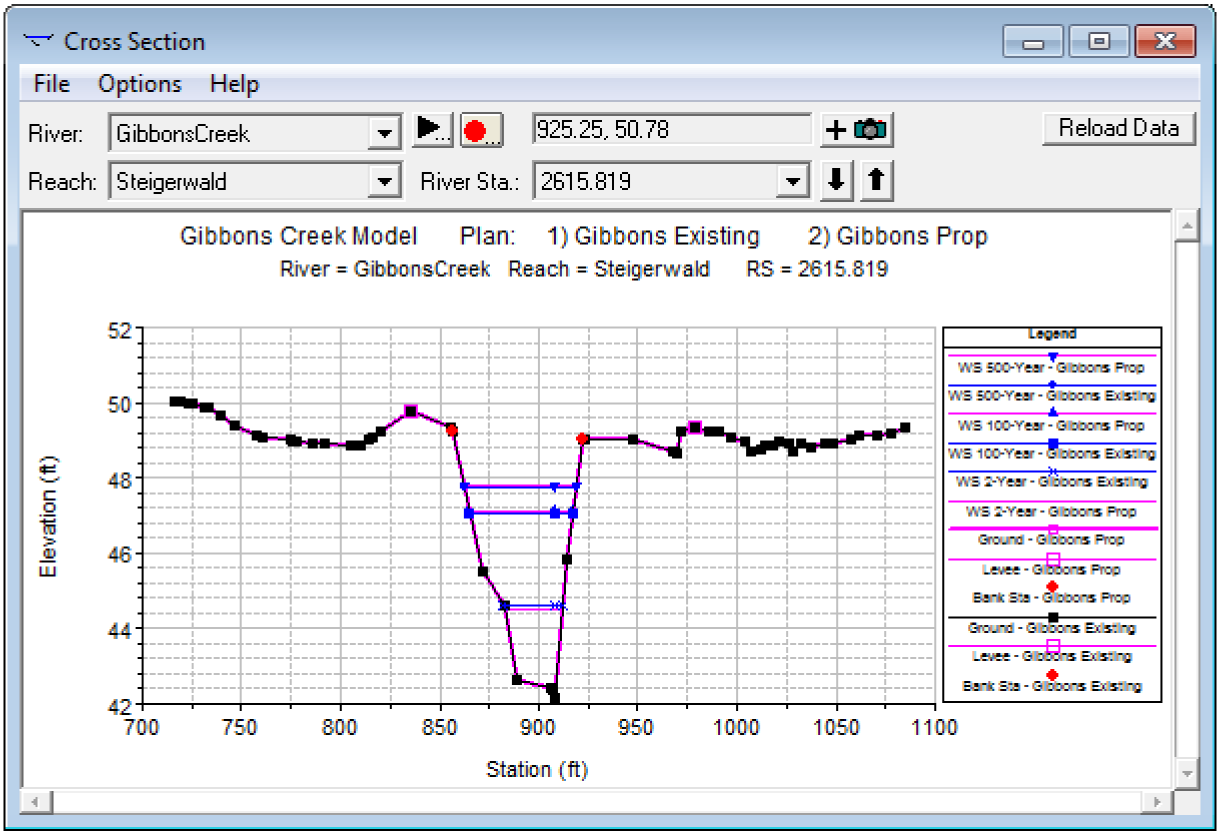

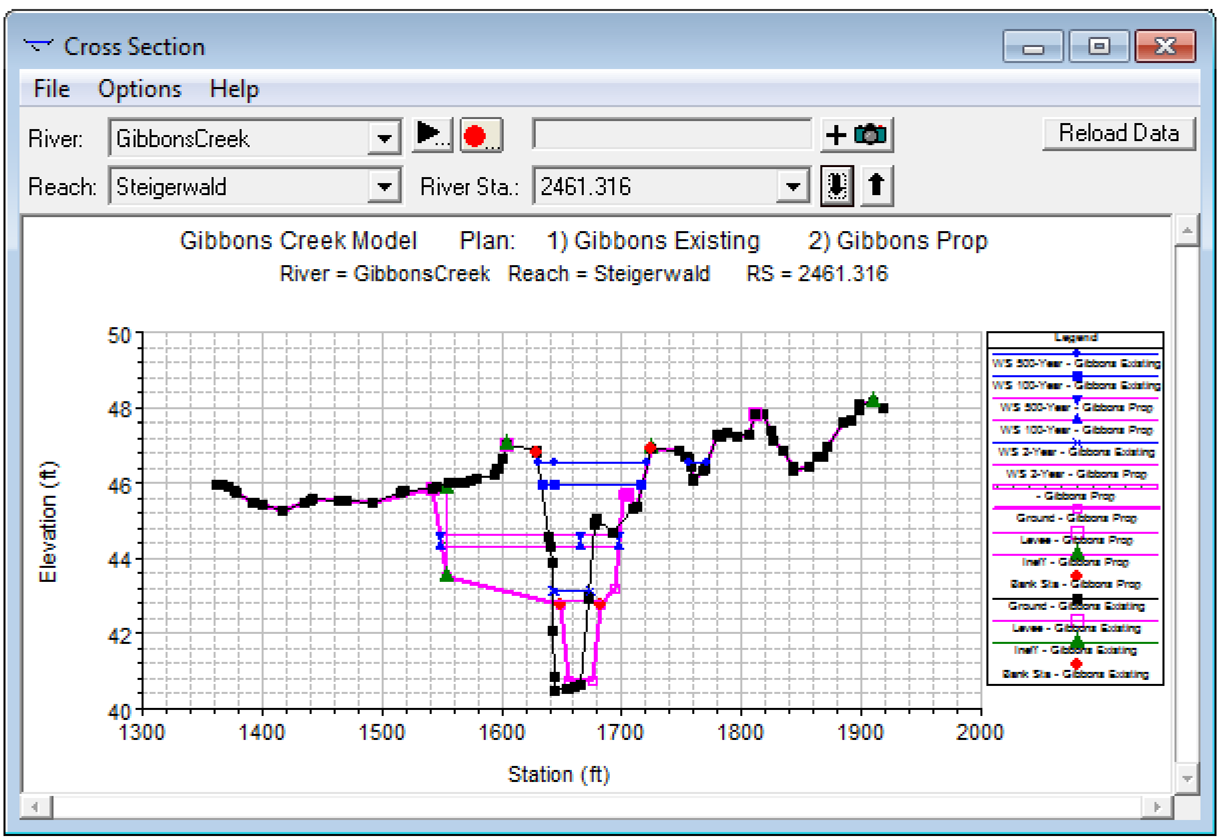

Figure 15
Existing Versus Proposed Cross Section Results
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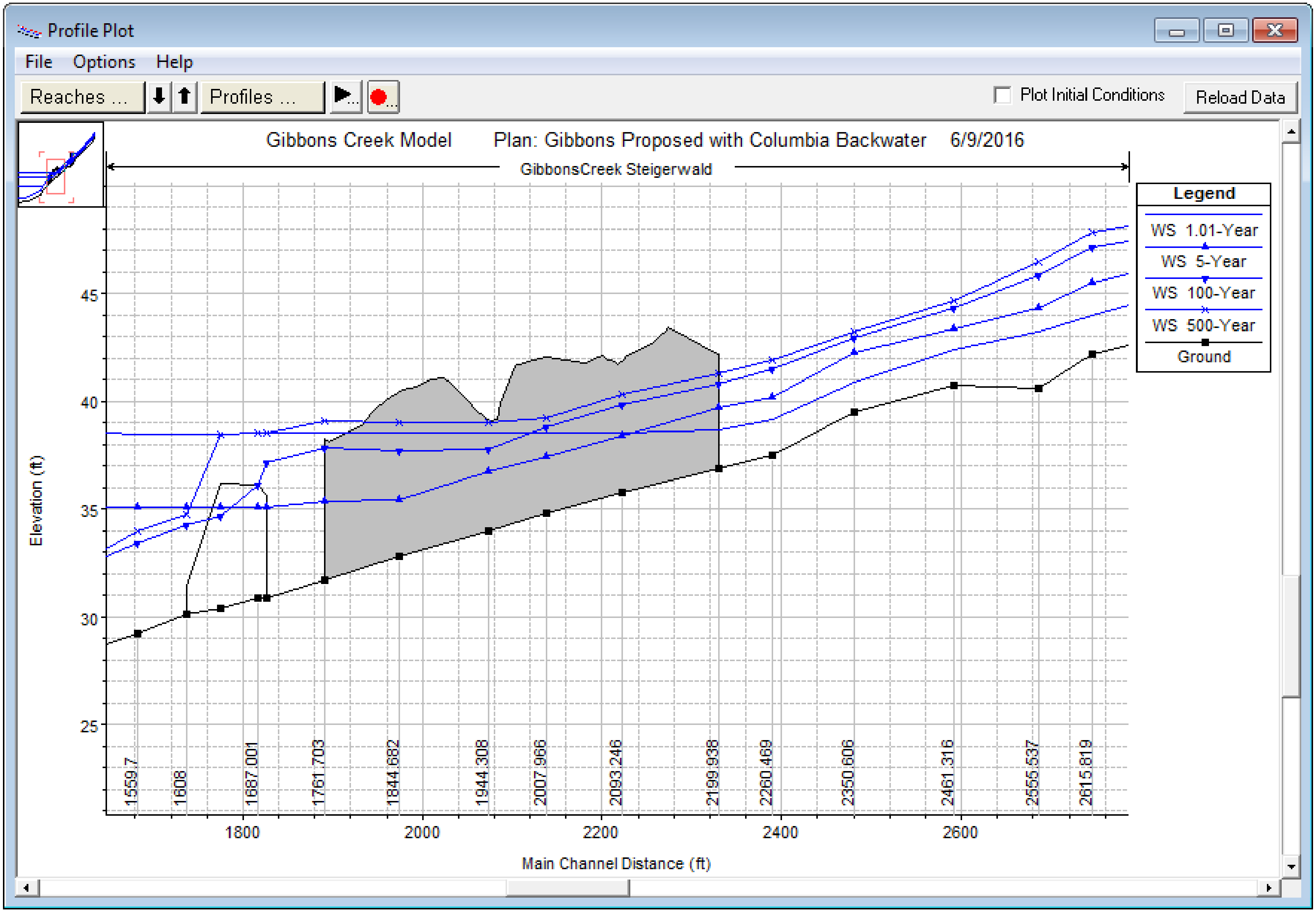
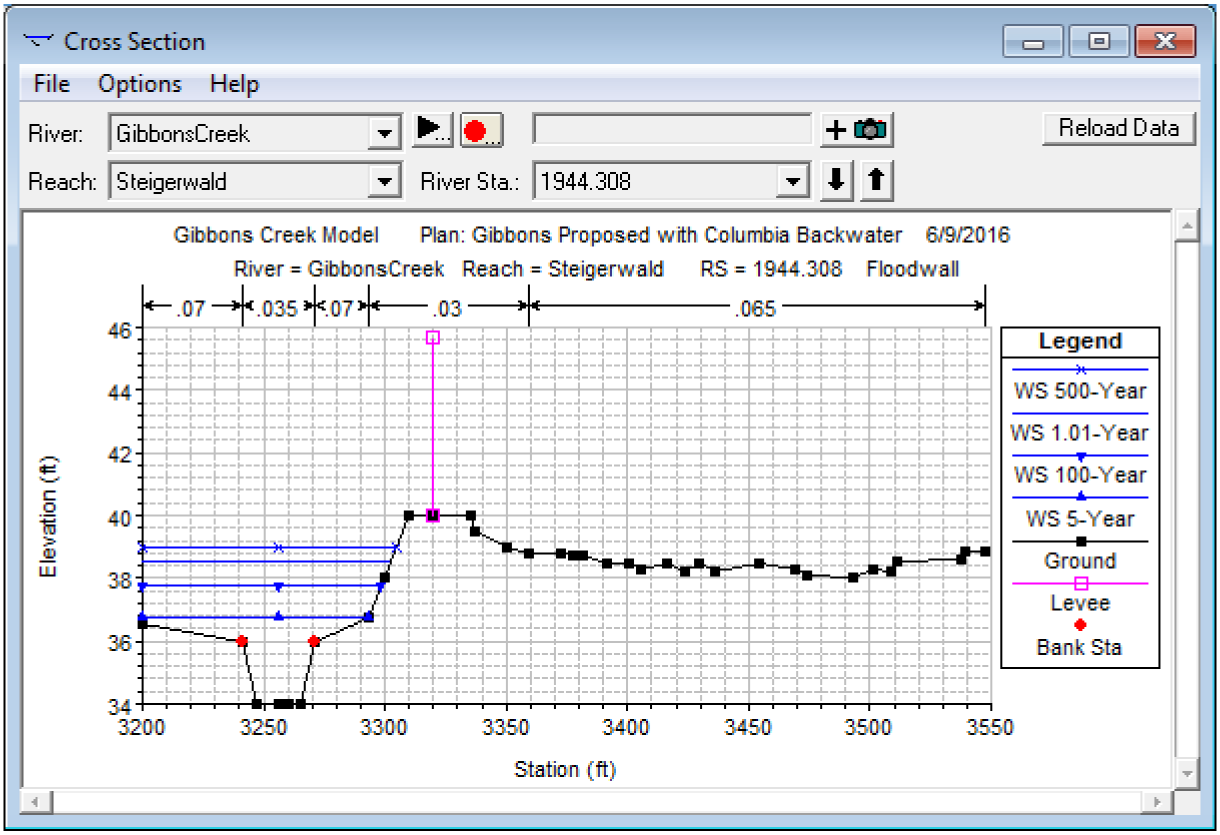


Steigerwald Design . D140746.02

Figure 16

Comparison of 500-Year Combined Frequency Water Surface Elevation Under Proposed Conditions.



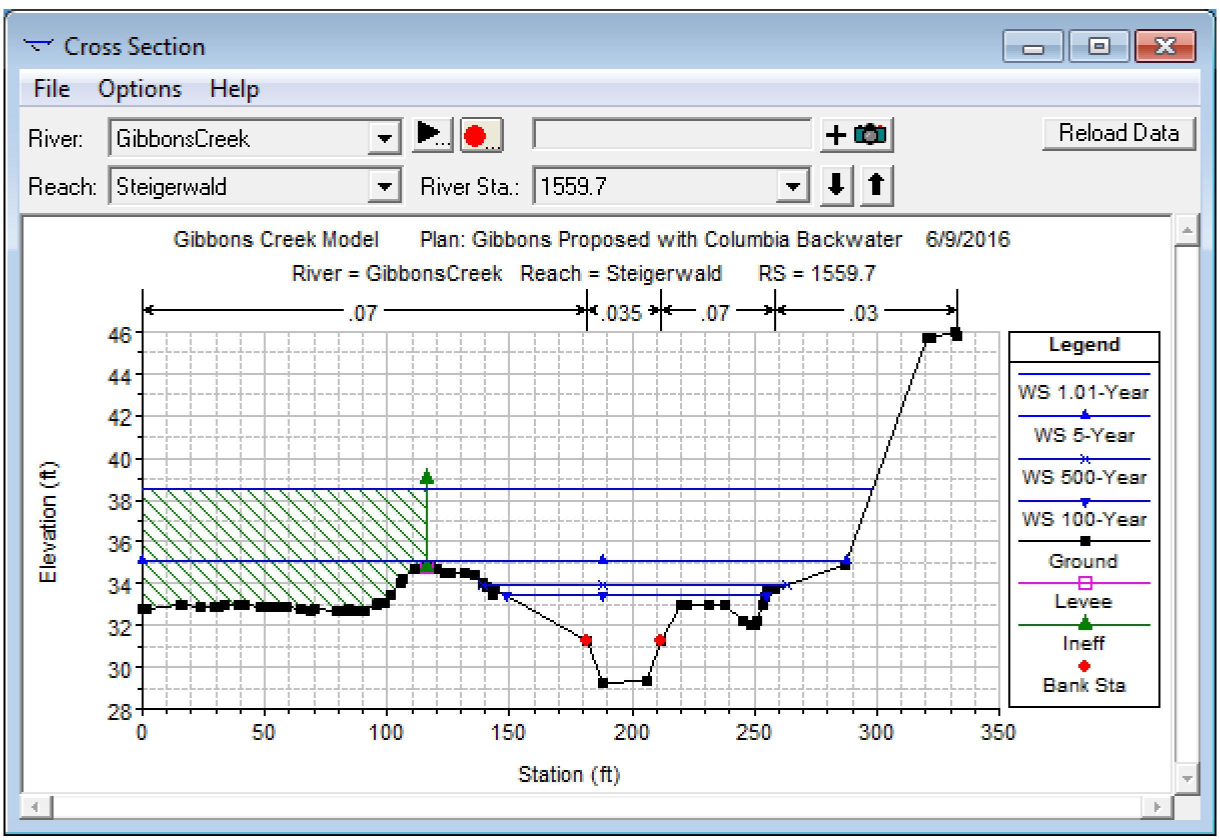


Figure 17
500-Year Combined Frequency Cross Section
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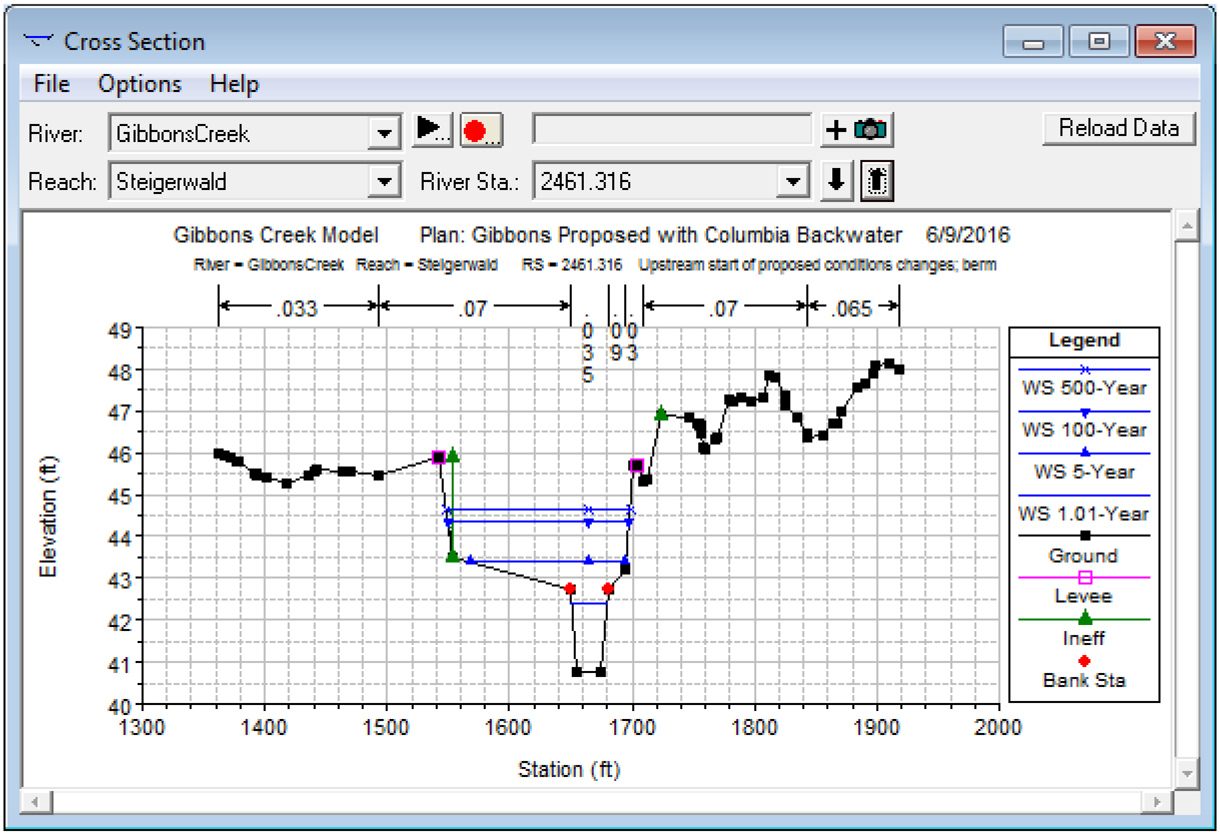

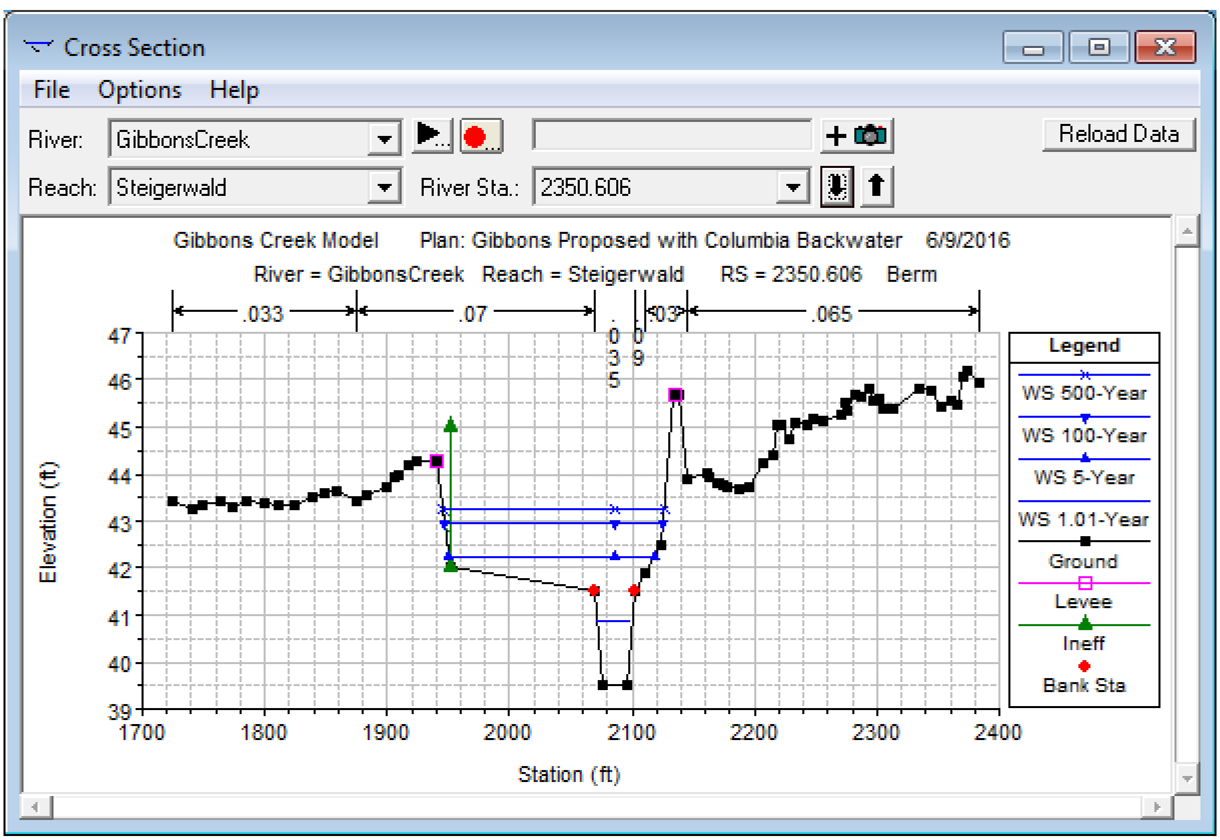

Figure 18
500-Year Combined Frequency Cross Section
Results at RS 2350 (Bottom) and 2461 (Top).

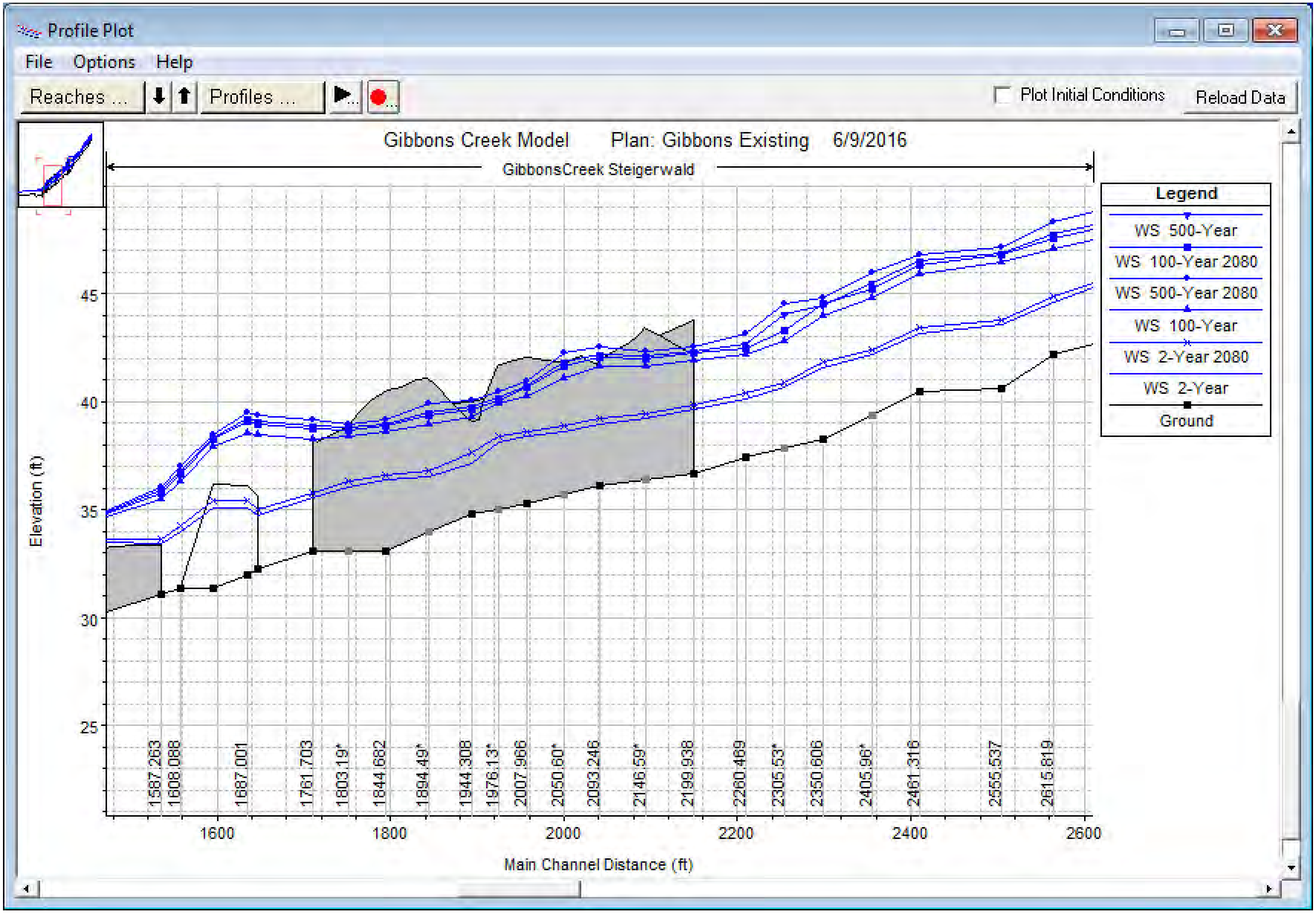

Figure 19
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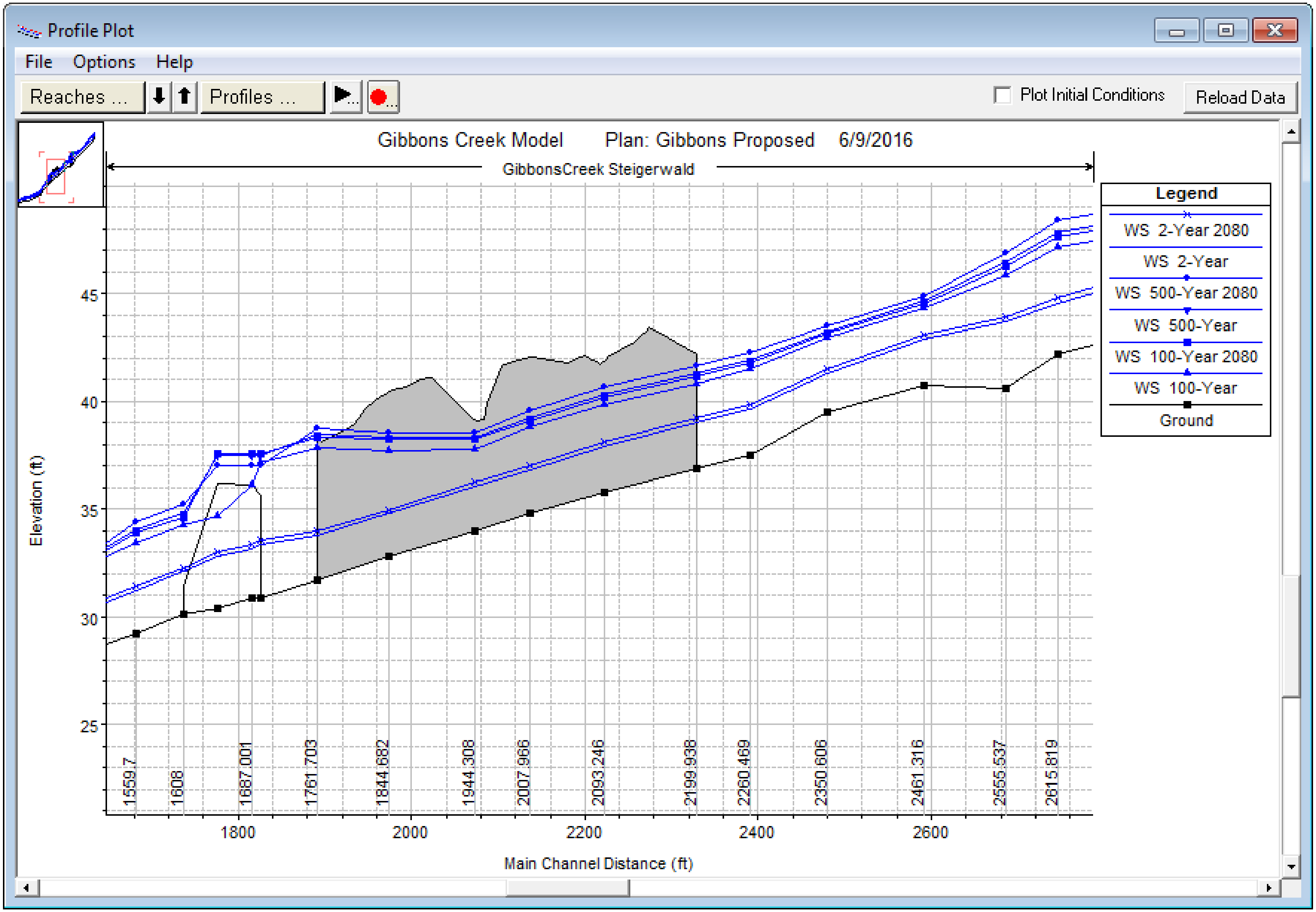


Steigerwald Design . D140746.02

Figure 20

Comparison of Climate Change Water Surface Elevation Profile Results Under Proposed Conditions.

STEIGERWALD FLOODPLAIN RESTORATION PROJECT

Basis of Design Report
60% Design

September 2017

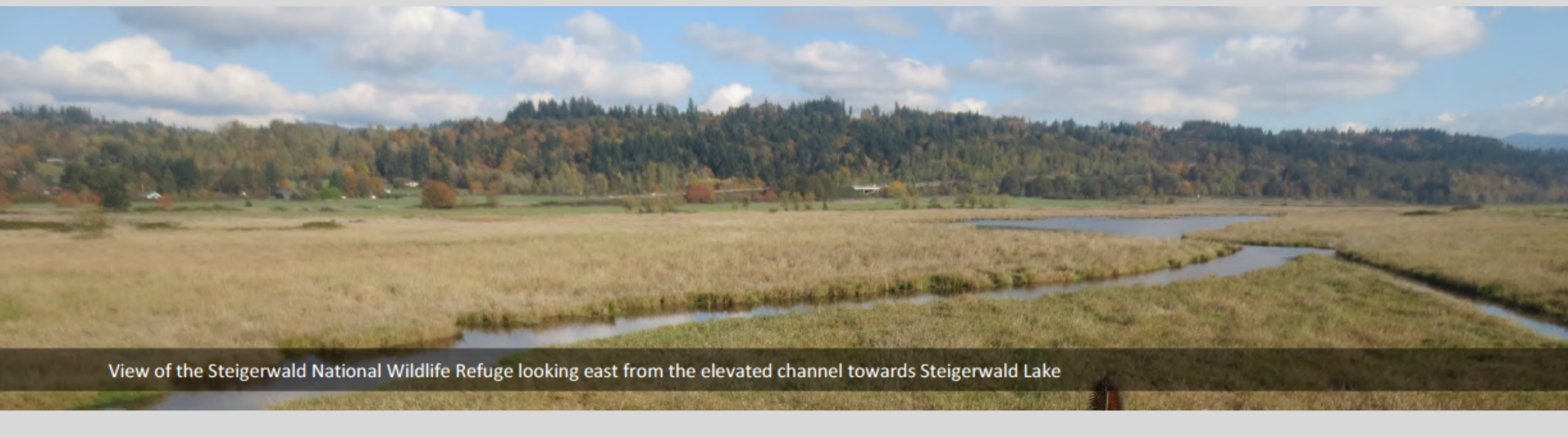
Prepared for

Lower Columbia Estuary Partnership

WOLF WATER RESOURCES

In Association with

Cornforth Consultants
KPFF Consulting Engineers
Laura Herbon Landscape Architect
WEST Consultants
Statewide Land Surveying



View of the Steigerwald National Wildlife Refuge looking east from the elevated channel towards Steigerwald Lake

Project Partners

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1 INTRODUCTION

1.1 Background

The Lower Columbia Estuary Partnership (Estuary Partnership) is proposing to restore approximately 1,000 acres of historic Columbia River floodplain habitat within the Steigerwald Lake National Wildlife Refuge (Refuge). The Refuge is located east of Washougal, Washington at the western boundary of the Columbia River Gorge National Scenic Area (CRGNSA). The Refuge is owned and managed by the U.S. Fish and Wildlife Service (USFWS). It is bounded by a private ranch to the east, the Columbia River to the south, the Port of Camas-Washougal (Port) to the west, and the Burlington Northern Santa Fe (BNSF) railroad to the north (**Figure 1-1**). The refuge property is contiguous except along the northern boundary where Washington State Route 14 (SR 14) runs east-west through the refuge. The Refuge extends along the historic Columbia River floodplain from River Mile (RM) 124 to 128. A perennial stream, Gibbons Creek, flows into the Refuge from its watershed north of the Refuge, and a second stream, Lawton Creek, borders the private ranch east of the refuge.

Important infrastructure within the Refuge includes two federally-authorized projects. The first federally-authorized project includes a five-mile-long levee constructed by the US Army Corps of Engineers (USACE) that separates the Refuge from the river. The levee is part of the federally-authorized Washougal Flood Damage Reduction (FDR) Project. The second, also a federally-authorized project, includes lands within the Refuge designated as mitigation for construction of the Bonneville Dam Second Powerhouse by the USACE. This mitigation included realignment of Gibbons Creek through a diversion structure, an elevated canal (Highline Canal), and a culvert and fish ladder before discharging into the Columbia River on the south side of the levee. The Port operates and maintains the Washougal FDR project. The Refuge (including the Gibbons Creek realignment project) is managed and maintained by the USFWS as part of the Ridgefield National Wildlife Refuge Complex.

1.2 Purpose & Overview

The purpose of the project is to restore floodplain processes and hydrologic connectivity between Gibbons Creek, the Columbia River, and the adjacent floodplain habitats within the Refuge. Restoration is intended to benefit Endangered Species Act-listed salmonids, as well as other native fish, wildlife, and plant species.

Due to the significant size of the site and the lack of other opportunities to restore nearby Columbia River floodplain, the proposed restoration at the Steigerwald National Wildlife Refuge presents a significant and rare opportunity for Columbia River Basin salmonid recovery. This opportunity includes generation of approximately five (5) survival benefit units towards USACE and Bonneville Power Administration (BPA) requirements under the Federal Columbia River Power System Biological Opinion mitigation requirements (ERTG 2015; NMFS 2008). Other benefits include eliminating maintenance dredging in Gibbons Creek; reducing interior flood risk to Port, City of Washougal (City), Washington Department of Transportation (WSDOT), and private infrastructure; improving fish passage; eliminating take of federally-listed salmonids during Gibbons Creek overflows; and improving the overall quality of fish and wildlife habitat. The effects of the project on all National Oceanic and Atmospheric Administration (NOAA) protected species will be addressed utilizing the BPA HIP III Programmatic Biological Opinion. Refer to Section 2.2 for fish presence characterization.

Restoration will be achieved by removing the levee and constructing channels between the Refuge and the river, as well as restoring Gibbons Creek's alluvial fan, as shown in **Figure 1-2** and in the construction drawings in **Appendix A**. New (setback) levees will be constructed at the east and west extents of the project to maintain flood protection for the Port and other adjacent properties and infrastructure. The SR 14 roadway along the northern boundary of the Refuge will also be raised approximately 3 feet to reduce water level impacts to the road. Gibbons Creek restoration will include removal of the diversion structure, the elevated canal, and the culvert and fish ladder at the downstream end of the creek. Other project measures include grading within the refuge to expand habitat, placing woody debris in floodplain channels to enhance aquatic habitat, and constructing pedestrian bridge crossings along the primary floodplain channels and Gibbons Creek. Wetlands and riparian areas within the Refuge will also be revegetated with native plant species.

1.3 Scope

The Estuary Partnership is being assisted by the following consultant team for restoration analyses and design:

- Wolf Water Resources (W2r): Hydraulic engineering, restoration design, stormwater design, permitting, and project management
- Cornforth Consultants*:* Levee design and geotechnical engineering
- KPFF Consulting Engineers: Flood wall design, roadway and closure structure design, and structural engineering
- WEST Consultants*:* Interior drainage analysis, risk and uncertainty analysis, and Columbia River and Gibbons Creek floodplain mapping
- Laura Herbon, Landscape Architect: Landscape architecture design
- Statewide Land Surveying (SWLS) and David Smith & Associates (DSA): Survey and photogrammetry

Agencies and partners supporting the Estuary Partnership in this project include USFWS, the Port, BPA, USACE, WSDOT, and the Friends of the Columbia Gorge (FOCG).

The project is being designed by licensed professional engineers, landscape architects, and land surveyors in the following areas:

- Professional engineers and land surveyors - Civil
    - Gibbons Creek
    - Floodplain connection channels
    - East levee interior drainage structures
    - Parking lot

    - SR 14 Roadway
- Professional Engineers - Geotechnical
    - West and east levees
    - Levee borrow sources
- Professional Engineers - Structural
    - SR 14 closure structure
    - Gibbons Creek floodwall
    - Pedestrian bridges and abutments (3)
- Landscape Architects
    - Expanded habitat areas
    - Planting areas
    - Trails and interpretive features

This Basis of Design Report describes analysis and design criteria developed to support the restoration project. The content and organization of this report is intended to facilitate reviews and meet requirements of BPA (as outlined in the HIPIII Manual, BPA 2014) and the USACE through the Section 408 design review process.

Sections of this report include:

- *Resource Inventory* –site context and existing conditions
- *Site Analysis and Evaluation* – summary of hydrologic, hydraulic, and geomorphic analyses
- *Design* – criteria and characterization of the restoration measures
- *Construction* –construction costs, sequencing, and specifications
- *Future Project Plans and Reviews* –project plans and reviews required under the USACE Section 408 review process

2 RESOURCE INVENTORY

The following section describes the past and present impacts on the channel, riparian, and floodplain conditions (flow management, constraints, lateral connectivity, tidal influence, and riparian conditions). Site context, historical conditions, and existing conditions have been documented in an Initial Feasibility Assessment (ESA 2014b), White Paper Discussion of USACE Section 408 Requirements (ESA 2014a), and a Conceptual Design Report (ESA 2015b). The following sections summarize this information.

2.1 Site Context

The Refuge was historically a dynamic portion of the Columbia River floodplain. Prior to floodplain alterations for agricultural and industrial uses in the early 1900s, the Refuge included the alluvial fans of Gibbons and Lawton Creeks, expansive emergent wetlands, and was dominated by bottomland hardwood forests and willow bottoms. Both creeks routinely flooded the site, and the Columbia River inundated the site annually for several months during the spring freshet and storm events. Historical aerial photographs show the floodplain to be a series of seasonally-flooded, open-water areas surrounded by vegetated marsh with meandering connection channels (**Figure 2-1**). Higher ground along the river-ward margins of the Refuge was likely formed by natural, fluvial floodplain processes of inundation and sedimentation from the Columbia River. Downstream of the Gibbons Creek alluvial fan, drainage channels connecting the floodplain depressions flowed west and eventually through low points in the natural fluvial levee of the Columbia River at the western end of the Refuge (Estuary Partnership 2013).

Habitat conditions within the Refuge have been significantly altered since the late 1800s and early 1900s. Primary alterations include:

- A levee separating the Refuge and other properties from the Columbia River;
- Channelization of Gibbons Creek, including the construction of an elevated canal;
- Conversion of wetlands and forests into agricultural lands;
- Railway and highway corridor construction along the northern margin;
- Regulation of the mainstem Columbia River hydrology;
- Urban and industrial development adjacent to the Refuge and associated alteration of Gibbons Creek hydrology; and
- Proliferation of invasive species.

Existing site conditions are summarized in **Figure 1-1** and described in more detail in the following sections.

2.1.1 Levee System

The levee and drainage system surrounding the Refuge is part of the Washougal FDR Project, a federally authorized and constructed urban flood damage reduction system (USACE 2010). The FDR Project protects approximately 1,800 acres of agricultural, industrial, commercial, residential, and Refuge lands and improvements. Construction was completed in 1966 by the USACE, and the Port is responsible for all operation and maintenance of the FDR Project (WEST 2012). The levee system was recertified in

2013, demonstrating that it meets FEMA accreditation requirements including providing protection from the Columbia River base flood event.

Drainage from over 12 square miles enters the interior of the FDR Project. Gibbons Creek contributes approximately 8 square miles, with the remaining contributed by local rainfall runoff. Flooding within the interior of the levee is evacuated by a system of pumps and gravity drains. With the current interior drainage system, significant portions of the Port and City infrastructure are mapped within the interior base flood extents (**Figure 1-1**), which have an associated elevation of 22.3 feet NAVD88. During the February 1996 flood event, the City's wastewater treatment plant (WWTP) which is located within the Washougal FDR Project (see **Figure 1-1**), flooded even though the Port's pump station was operating at maximum capacity. Portions of the Port's Industrial Park also flooded during the 1996 event.

2.1.2 Gibbons Creek

After construction of the FDR Project in 1966, Gibbons Creek discharged into the FDR interior drainage system. Gibbons Creek, along with local rainfall runoff into Steigerwald Lake, flowed in its historic/remnant alignment to the west end of the levee system before flowing through the tide gate or being pumped over the levee by the pump station (USACE 2010). Gibbons Creek was later channelized and realigned to cross SR 14, slightly east from its original location, when SR 14 was constructed in 1971. This realignment included meandering the creek to flow into Steigerwald Lake. In 1992, as part of the mitigation requirements for the construction of the Bonneville Second Powerhouse, Gibbons Creek was realigned by the USACE into an elevated canal. This creek realignment included a diversion structure (sluice gate/lateral overflow weir – **Photo 2-1**) immediately south of SR 14 within Gibbons Creek's historic alluvial fan. The structure was designed to divert up to 70 cubic feet per second (cfs) of Gibbons Creek into the elevated canal, also referred to as the Highline Canal. The canal is approximately 6,000 feet long, and bisects Steigerwald Lake before discharging into the Columbia River via an 84-inch culvert through the levee and fish ladder. Flows above 70 cfs spill into the diversion structure's lateral overflow, into the Gibbons Creek remnant channel, and eventually reach the Port's pump station at the west end of the Refuge and Industrial Park (USACE 2012a).

Photo 2-1: Gibbons Creek Diversion Structure

The USFWS operates and maintains the Gibbons Creek diversion structure and Highline Canal. During storms, bedload and debris from the creek are commonly deposited within the structure. The sediment and debris then cause even modest flows (less than 70 cfs) to spill into the lateral overflow and remnant Gibbons Creek channel where they must be pumped through the levee to the Columbia River[1]. Regular debris accumulations result in significant pumping costs (up to $100,000 per year in electrical costs

[1] In a 2010 joint aquatic resource permit application, the USFWS stated that "during normal winter rains, Gibbons Creek frequently flows over the concrete weir" and into Refuge wetlands.

alone), increased interior flood risk, and increased flood risk to upstream infrastructure (SR 14[2] and a mobile home park). In addition, USFWS staff must regularly remove debris and sediment to minimize overflows and to maintain conveyance below SR 14. An average of 280 cubic yards (cy) of material per year was removed between 1997 and 2011 (Estuary Partnership 2015). Peak sediment removal occurred in 1995 (2,700 cy) and 1996 (5,000 cy). These values represent the material that is deposited due to the diversion structure; however, a significant amount of sediment is transported through the overflow weir and into the overflow channel. Additional information on sediment removal quantities can be found in Appendix D-2.

Annual removal of sediment and debris requires permitting, significant Refuge resources, and typically must be done under emergency circumstances during fall and winter storm periods. During these times of the year, salmon may be spawning or their eggs may be incubating in stream gravels and are therefore most vulnerable to in-channel disturbance. Additionally, the channel cannot be dewatered during winter and spring, therefore juvenile lamprey, which burrow into stream substrate, cannot be effectively removed prior to dredging. USFWS staff has removed as many as 147 juvenile lamprey when the work area is dewatered during summer and fall dredging.

In addition to reducing interior flood risk and pumping costs, the realignment of Gibbons Creek in 1992 was intended to provide fish passage into Gibbons Creek via the fish ladder and elevated channel. However, as noted above, sedimentation in the Gibbons Creek diversion structure reduces channel capacity causing water to overflow eventually draining though Gibbons Creek's remnant channel. Fish have been observed in the overflows where survival is unlikely. These overflows result in take of Endangered Species Act (ESA) - listed salmonids due to (1) entrapment in reed canary grass (*Phalaris arundinacea*) located immediately downstream of the lateral overflow, (2) lethal summer temperatures in the remnant Gibbons Creek channel, and (3) becoming entrained in the pumps that form the primary outlet to the Columbia River during the freshet (when most juvenile salmonids are attempting to out-migrate).

The fish ladder (**Photo 2-2**) at the downstream end of Gibbons Creek is also perched two to three feet above the Columbia River during low Columbia River stages, which typically coincide with upstream migrations of lamprey and Chinook and coho salmon. The ladder is also designed with hydraulic drops (jump heights) that exceed 1 foot, which does not meet current adult or juvenile fish passage criteria.

Photo 2-2: Gibbons Creek fish ladder looking south.

[2] USFWS staff report that the SR-14 bridge commonly has zero to six inches of freeboard during common winter storm events.

2.2 Fish Presence

Historically, Gibbons Creek supported coho salmon (*Oncorhynchus kisutch*), steelhead (*O. mykiss*), coastal cutthroat trout (*O. clarki*), Pacific lamprey (*Lampetra tridentata*), and western brook lamprey (*L. richardsoni*) (Barndt et al. 2003). Other species, including chum (*O. keta*) and fall Chinook salmon (*O. tshawytscha*), also may have spawned in the creek when conditions permitted. Similarly, these same fish species likely accessed the off-channel floodplain habitat historically at the project site. Before the levees were constructed, high waters of winter floods and the spring freshet would permit fish to access the floodplain wetlands providing high quality refuge and rearing habitat. Floodplain habitats such as those historically present at the Refuge are documented as being an important rearing habitat for salmonids and lamprey, including federally listed species from throughout the Columbia River basin.

After the construction of the levee, tidegate, and pumping station in 1966, Steigerwald Lake and the surrounding floodplain were isolated from periodic flooding and fish passage was severely limited. At Columbia River stages above 11.5 feet NAVD88 elevation, the tidegates close and adult upstream migrating fish could not enter Gibbons Creek to spawn and juvenile out-migrants were directed through the pump station (Bricknell 1988 in Barndt et al. 2003). Fish passage was thus limited to lower river stages, when water temperatures in the floodplain and lower river often are at stressful, or lethal, levels.

In 1992, as part of the mitigation requirements for the construction of the Bonneville Second Powerhouse, Gibbons Creek was realigned by the USACE into an elevated canal, bypassing Steigerwald Lake, and out to the Columbia River through a fish ladder. This realignment of Gibbons Creek was intended to provide bidirectional fish passage through the Refuge and avoid the pumping station. The Gibbons Creek diversion structure and canal disconnects Gibbons Creek from interacting with the floodplain until modest flow events (sometimes less than 70 cfs due to debris and sediment buildup) spill into the lateral overflow weir and into the remnant Gibbons Creek channel. During these overflow events, adult and juvenile salmonids are frequently found stranded within the floodplain. Fish that survive these overflow events typically are not able to re-enter Gibbons Creek and face low valued habitats in the floodplain that are impaired by seasonally high (often lethal) water temperatures and minimal vegetative and structural diversity.

Photo 2-3: Steelhead swimming across the Gibbons Creek overflow weir. (December 2015)

Although use of the fish ladder has not been documented, migrating species such as adult and juvenile coho and steelhead, Pacific lamprey, and largescale sucker (*Catostomus macrocheilus*) were observed in Gibbons Creek during spawning ground surveys and out-migrant salmonid trapping surveys by USFWS (Barndt et al 2003). Some fish may still pass through the tidegates.

To date, no sampling has occurred to determine whether juvenile Columbia River chum salmon, juvenile LCR Chinook salmon, or juvenile salmonids from up-river Evolutionary Significant Units (ESUs) use the greater Steigerwald project site as off-channel habitat. Several studies collected fish presence data, however, at analogous habitats within the vicinity of Steigerwald (Sagar et al. 2013; Johnson et al. 2011; Schwartz et al. 2013). Based on data from these studies, it is likely that both ESA-listed and non-listed salmonids from ESUs above and below Bonneville Dam would utilize the Steigerwald site during out-migration. For example, sampling at Rooster Rock State Park (Mirror Lake), the Sandy River Delta, and Franz Lake found juvenile steelhead and Chinook, coho, and chum salmon at all sites. Overall, Chinook salmon were the most abundant juvenile salmon species, and catch rates were highest during April, May, and June with the second highest densities occurring in winter months. The following Chinook salmon reporting groups (listed along with the relevant ESU and ESA status) were detected during the sampling efforts:

- Upper Columbia River Summer/Fall – Upper Columbia River Summer/Fall ESU (not listed)
- Snake River Fall – Snake River Fall Run ESU (threatened)
- Deschutes River Fall – Deschutes River Summer/Fall Run ESU (not listed)
- Spring Creek Fall – Lower Columbia River ESU (threatened)
- West Cascades Spring – Lower Columbia River ESU (threatened)
- West Cascades Fall – Lower Columbia River ESU (threatened)
- Willamette Spring – Upper Willamette River (threatened)

Relative abundance of these reporting groups varies between sites. The majority of fish from the Lower Columbia River and Willamette River ESUs were marked hatchery fish. The majority of fish collected from the other three reporting groups (Upper Columbia, Deschutes, and Snake River) were unmarked. It is also possible that up-river steelhead ESUs utilize some of the sample sites; however, genetic sampling has not been completed at other sites to differentiate between LCR and up-river stocks.

The 2012 Lower Columbia River Ecosystem Monitoring Program (EMP) report (Sagar et al. 2013) is a synthesis of the data collected for this program from 2005 to 2010. Sample sites for this study included several sites in the Columbia River Gorge between Steigerwald and the Bonneville Dam that are relevant to the Steigerwald project, including Sand Island, Franz Lake, Pierce Island, and Hardy Slough. The report states that compared to other sites sampled for this program elsewhere in the lower Columbia River (Reaches C-H), the sites in the Gorge had the greatest diversity of salmonid species, with significant numbers of unmarked and marked coho, chum, and a few steelhead, as well as Chinook. Juvenile Chinook salmon were found at all sampling sites between April, when sampling began, until June or July, with a few sites continuing to support Chinook salmon in August. Genetic testing indicated that juvenile Chinook salmon from stock originating throughout the Columbia Basin were present at the EMP sample sites.

Peak Chinook densities for were found in May and June, the period when the restored Refuge would be inundated by the Columbia River's spring freshet, and therefore easily accessible to salmonids.

Due to the similarities between the Refuge and the EMP sample sites, it is reasonable to assume that restoring access between the river and the Refuge wetlands would result in use by a similar composition of juvenile salmon species.

Between 2007 and 2010 a collaborative effort of the Pacific Northwest National Laboratory, the Oregon Department of Fish and Wildlife, the National Marine Fisheries Service, and the University of Washington (funded by BPA) investigated the ecology and early life history of juvenile salmonids within shallow tidal freshwater habitats in the Lower Columbia River (Johnson et al. 2011). The study site for this effort was primarily in and around the Sandy River Delta (SRD) directly across the Columbia River from the Refuge and included a sample site on the north side of Reed Island adjacent to the Refuge. Due to the proximity of the sampling and the similarities between the Sandy River Delta and the proposed conditions at Steigerwald, the study results are presented here as a proxy for juvenile salmonid use of the Refuge, once restored. Additionally, acoustic receivers deployed by the study along the northern fringe of the Sandy River Delta and the southern fringe of the Refuge (the Reed Island Channel) indicated that a "greater percentage of acoustic-tagged yearling and subyearling Chinook salmon used the route between Reed Island and the Washington shore…than the route along the Oregon shore". This further bolsters the suitability of the Sandy River Delta study as an indicator of salmonid use of the Steigerwald site, if restored.

The majority of juvenile salmonids were found using shallow water habitat during spring, and to a lesser extent during winter. Chinook and coho were found throughout the year. Chum salmon were found during winter, and in the spring at the mouth of the historic Sandy River channel and at the sample site in the channel between Catham Island and the Thousand Acres project site (Johnson et al. 2011). A genetic stock identification analysis was conducted for Chinook sampled. Results of the analysis, estimated percentage composition of the Chinook sampled, and ESA status are as follows:

- Spring Creek Group Tule Fall (35%) – Threatened
- Upper Columbia Summer/Fall (33%) – Not listed
- West Cascade Tributary Fall (15%) - Threatened
- Willamette River Spring (8%) - Threatened
- Snake River Fall (3%) - Threatened
- Deschutes River Fall (3%) – Not listed
- West Cascade Tributary Spring (2%) - Threatened

The majority of salmonids using the Delta habitat were unmarked (Johnson et al. 2011).

The study suggests that juvenile salmon use shallow tidal freshwater habitats, such as those found at the SRD, for rearing throughout the year. There was not conclusive evidence found by this study to indicate whether wetland, off-channel, or main channel habitats were more important for juvenile salmon. Therefore, the evidence supports enhancement of access and habitat quality to all of these shallow tidal freshwater habitats (Johnson et al. 2011).

As part of the Estuary Partnership Action Effectiveness Monitoring Program, juvenile salmon genetic data collected at the near-by Mirror Lake restoration project site during 2008 and 2011 confirmed the presence of juvenile salmonids utilizing off channel habitat of a floodplain wetland system. The results of this study show a comparable pattern to that observed at sites sampled for the EMP and the Sandy River Delta. The unmarked salmon sampled at Mirror Lake belonged to a diverse array of stocks including Upper Columbia summer/fall Chinook, Snake River fall Chinook, and Deschutes River fall Chinook, as well as West Cascades fall and Spring Creek Group fall Chinook stocks from the Lower Columbia River

ESU. In most years, unmarked juvenile Chinook were present only through June; however, in 2010, unmarked juvenile Chinook were present through August (Schwartz et al. 2013).

Multiple local and upriver species and populations of juvenile and adult salmonids would benefit from the reconnection of Gibbons Creek and the Refuge floodplain habitat to the Columbia River as a result of the proposed project.

2.3 Endangered Plant Species

Populations of two federally listed plant species have been experimentally introduced within the Refuge: Nelson's checkermallow (*Sidalcea nelsoniana*) and golden paintbrush (*Castilleja levisecta*). Three plots of checkermallow, totaling 575 plugs were planted in 2011. Golden paintbrush was seeded in two plots in 2014 and supplemented by 852 plugs, split between the sites, in 2015. Each of these species are listed as threatened under the ESA and are currently being managed by the USFWS for their recovery via their published respective Recovery Plans (USFWS 2010; USFWS 2000).

The USFWS has evaluated the potential impacts to these two species through an Intra-Service Biological Evaluation and formal consultation (USFWS 2016). The golden paintbrush plots were found to be above the elevation that is likely to be impacted by the proposed action. However, considering the presence of golden paintbrush in the project vicinity, USFWS has determined that the proposed project may affect, but is unlikely to adversely affect this species.

Only two plots of the Nelson's checkermallow are within the project area. Hydrologic modeling for the project design indicate that under proposed conditions these two plots would experience increased inundation from Columbia River flooding at and above the 50% ACE. The inundation would likely coincide with the post-emergence of the plants and may impact plant survival or seed production. Thus, it was determined that a portion of the population may be affected through periodic inundation. Therefore, the USFWS has determined that the proposed project may affect and likely to adversely affect Nelson's checkermallow. However, after reviewing the current status of Nelson's checkermallow, the environmental baseline for the Refuge, and the effects (direct, indirect, and cumulative) of the proposed project, it is the USFWS's biological opinion that the action, is not likely to jeopardize the continued existence of Nelson's checkermallow or its habitat. The USFWS identified continued monitoring, management, and further outplants as conservation recommendations for the project.

2.4 Existing Habitats

Much of the vegetation at the Refuge has been altered relative to historic conditions. The oldest recorded mapping of vegetation on the Refuge is c. 1860 Government Land Office (GLO) survey data (**Figure 2-2**). This mapping includes areas of open water and wetland, dry and wet prairie, and riparian and wetland forest. Land conversion to agricultural uses like livestock grazing and hay production account for early changes in the vegetation communities at the site. Actions to support these new uses included land clearing, drainage and water impoundment, and the introduction of pasture grass and other non-native plant species.

2.4.1 Riparian

Riparian and wetland forest communities historically occupied the floodplain and natural fluvial levee along the Columbia River. This area would have been frequently flooded at a range of depths, frequencies, and durations resulting in a complex mosaic of plant species and age classes. Levee construction in 1966 reduced the frequency and extent of periodic Columbia River flooding, changing the natural disturbance regime, and eliminating conditions needed to support riparian forest regeneration. As a result of these changes and clearing activities, the riparian forest that remains today has a much smaller spatial extent than it did historically and is relatively homogeneous in both age and species composition (**Figure 2-3**).

Riparian vegetation communities include those that occur along the Columbia River and form the boundary between wetlands and uplands. Riparian communities include mature cottonwood-ash gallery forests and scrub-shrub dominant communities. The total estimated acres of cottonwood-ash forest at the Refuge is 47 acres (USFWS 2005). Scrub-shrub vegetation communities comprise an estimated 30 acres (USFWS 2005).

The forested cottonwood-ash riparian areas occur along the shoreline of the Columbia River and in areas around Redtail Lake. Mature black cottonwood (*Populus trichocarpa*) trees dominate the tree canopy, while blackberry (*Rubus sp.*), Scouler's willow, and Pacific willow *(Salix scouleriana* and *S. lasiandra)* are dominant in the mid-story (USFWS 2005, Estuary Partnership 2017). Reed canary grass, Canada thistle (*Cirsium arvense*), and common teasel *(Dipsacus fullonum)* are present in the herb layer. Oregon ash (*Fraxinus latifolia*) is also characteristic of the riparian communities in the area and occurs in both the shrub and canopy layer. These riparian forests are small, fragmented, and interspersed with non-native species (USFWS 2005).

Scrub-shrub riparian communities include woody vegetation less than 20 feet tall, including true shrubs and young trees. Plant species present typically include red alder (*Alnus rubra*), snowberry (*Symphoricarpos albus*), red-osier dogwood (*Cornus sericea*), willows, blackberry (*Rubus sp.*), and nettles (USFWS 2005).

2.4.2 Wetland

The GLO mapping of the site shows extensive areas of seasonally and perennially wet prairie as well as water and wetlands. Wetlands still occupy much of this area. A wetland delineation was recently conducted on the Refuge, and a total of 617.1 acres of wetlands were found in 10 distinct wetland areas within the study area (Estuary Partnership 2017).

Steigerwald Lake and Straub Lake wetlands (316 and 219 acres, respectively) are largely coincident with the water and wetlands area in the GLO map. Steigerwald Lake is comprised of a series of depressional, emergent, palustrine wetlands which are also overwhelmingly dominated by reed canary grass, with pockets of English plantain (*Plantago lanceolata*), black cottonwood, soft rush (*Juncus effusus*), birds-foot trefoil (*Lotus corniculatus*), field horsetail (*Equisetum arvense*), Armenian blackberry (*Rubus armeniacus)*, false ryegrass (*Schedonorus arundinaceus*), and swamp smartweed (*Persicaria hydropiperoides)*. Straub Lake is a depressional, emergent, palustrine wetland. The USFWS manages the water level of Straub Lake for waterfowl habitat using flashboards mounted to culverts that pass water through the internal dikes. The dominant species within and surrounding this wetland is the non-native and invasive reed canary grass. Native species around the lake included soft rush, swamp smartweed, fox sedge (*Carex vulpinoidea*), and narrow-leaf bur-reed (*Sparganium angustifolium*). Other non-native species along the wetland boundary included birds-foot trefoil, Canada thistle, field horsetail, common velvet grass (*Holcus lanatus*), false ryegrass, and Armenian blackberry.

The shape of present-day Scaup Lake wetland (19 acres) is clearly visible in the GLO mapping as riparian wetland forest, while Redtail Lake wetland (44 acres) is a portion of a larger riparian wetland forest. Scaup Lake is a depressional, emergent, palustrine wetland dominated by soft rush and reed canary grass, with substantial areas of native wapato (*Sagittaria latifolia*) in the deeper water areas and scattered stands of broad-leaf cattail (*Typha latifolia*). Redtail Lake is an emergent, palustrine wetland dominated by reed canary grass with smaller areas of stinging nettle (*Urtica dioica*) and swamp smartweed. A narrow riparian fringe remains north of Redtail Lake.

In addition to these large wetlands, there are also a handful of smaller emergent wetlands on the site. These include two small slope, emergent, palustrine wetlands were located south of Scaup Lake dominated by reed canary grass, false ryegrass, and small areas of bearded wild rye (*Elymus caninus*) and Douglas spirea (*Spiraea douglasii*). Two small depressional, emergent, palustrine wetlands were delineated that are dominated by reed canary grass, with lesser amounts of false ryegrass and a small stand of black cottonwood.

2.4.3 Grassland

A portion of the Refuge is maintained in short (3 to 6 inches tall), perennial grass through mowing, grazing, and haying. The purpose of this land management is to provide food in the form of short grasses for wintering western Canada geese and cackling Canada geese, a population that averages 2,000 birds each winter (USFWS 2005). To provide habitat for nesting birds and other wildlife, fields that appear to have minimum foraging use have been taken out of short grass management efforts and left undisturbed. The NWR currently has 293 acres of managed fields and 215 acres of unmanaged fields (USFWS 2005). The managed fields host a mix of pasture grasses and invasive herbs such as rough bentgrass *(Agrostis scabra)*, red fescue *(Festuca rubra)*, reed canary grass, velvet grass, and various bulrushes (*Juncus* sp.). Areas that are unmaintained appear to be overwhelmingly dominated by reed canary grass.

During the wetland delineation, upland grassland plots were assessed for vegetation characteristics and confirmed typical species composition (Estuary Partnership 2017). Reed canary grass remained the dominant plant species and other herbs and pasture grasses present included Canada thistle, nightshade (*Solanum dulcamara*), bentgrass (*Agrostis* sp.) tall fescue (*Schedonorus arundinaceus*), sweet vernal grass (*Anthoxanthum odoratum*), English plantain *(Plantago lanceolata),* and blackberry (*Rubus sp.*).

2.4.4 Oak Woodland/Savanna

The historic presence of Oregon white oak is indicated in the GLO mapping as a constituent of both the dry upland prairie and riparian and wetland forest communities. Because oak trees are very slow growing and young trees are vulnerable to mowing and browsing, there has been a gradual reduction in the extent of these trees with European settlement. Oak woodlands are recognized as a globally critically imperiled community because of the small number of occurrences, small global range, and high threats.

In 2003, the Washington State Department of Natural Resources (WDNR) adopted the 976-acre Washougal Oaks Natural Resource Conservation Area and Natural Area Preserve, located north of the eastern end of the Refuge. Within this preserve is the largest Oregon white oak community in western Washington and one of fewer than 20 total occurrences in the world (USFWS 2005). A very small piece of this community occurs within the project area where it extends south of the railroad track, adjacent to SR 14 providing valuable habitat diversity. The Oregon white oak community is comprised of Oregon white oak (*Quercus garryana*), oval leaf viburnum (*Viburnum ellipticum*), and poison oak (*Toxicodendron diversilobum*) (Chappell 2006). Other shrub species that may occur within the white oak assemblage include snowberry, oceanspray (*Holodiscus discolor*), serviceberry (*Amelanchier alnifolia*), Indian plum (*Oemleria cerasiformis*), tall Oregon grape (*Mahonia aquifolium*), trailing blackberry (*Rubus ursinus*), and baldhip rose (*Rose gymnocarpa*) (Chappell 2006). Douglas fir (*Pseudotsuga menziesii*) may also occur in the canopy (Chappell 2006).

2.5 Wildlife

The project area, which is almost entirely within the Refuge, has been actively managed for wildlife since its establishment in 1987. More than 20 species of mammals, 15 species of reptiles and amphibians, and a wide variety of insects, fish, and plants have all been identified on the refuge (USFWS 2010b).

Waterfowl have been of primary management focus on the Refuge, especially providing year-round support for breeders, migrant, and wintering species such as cackling goose (*Branta hutchinsii*), a species formally managed under a Pacific Flyway Management Plan (USFWS 2005). The Plan identifies the importance of habitat provided by the Refuge. Ongoing management actions at the Refuge include maintaining large expanses of short and/or disturbed grassland by annual mowing and haying from June to July and grazing from May to October (Chmielewski personal communication). USFWS also manages specifically for purple martin (*Progne subis*), a species identified as a “Conservation Target” of the Refuge (USFWS 2005). Management of this species entails ensuring access to large wetland complexes and appropriate nesting cavities that are typically human-made nesting structures.

Wildlife are discussed in the context of the habitat they most frequently occupy. Wildlife habitats available in the action area are riparian cottonwood riparian forest and riparian forested-shrub wetlands; wetland complexes of open water and emergent wetland; and maintained grassland.

2.5.1 Riparian

Riparian cottonwood (gallery) forest forms long, mostly contiguous patches of large mature trees (greater than 30 years-old) that create a mostly intact canopy. This habitat provides a corridor for wildlife to move along riparian system and into adjoining habitats. The mature cottonwoods that dominate this habitat vary in physical condition and compose a mix of standing mature trees, dead or dying individuals (i.e., snags), those with detached crowns and/or limbs, and large downed woody debris. Each provides important structural features for this relatively high-quality habitat. Standing mature trees provide habitat for large tree-nesting birds such as great blue heron, red-tailed hawk (*Buteo jamaicensis*), pileated woodpecker (*Hylatomus pileatus*), and forest hawks (*Accipiter* sp.). A moderately sized, active great blue heron rookery (approximately 30 nests) is present in the southwestern corner of the study area. This rookery site was likely established because of its large trees, good access to foraging areas, and relatively low disturbance from humans or other predators. Dead or dying trees, including snags and those with detached crowns and/or limbs, are used by cavity-nesting birds such as woodpeckers (Picadae), swifts (Apodidae), swallows (Hirundinidae), wood duck (*Aix sponsa*), and great-horned owl (*Bubo virginianus*), as well as several bat species (Chiroptera), raccoons (*Procyon lotor*), and opossum (*Didelphis virginianus*). All seek cover in the structure it provides. Large downed woody debris provides a diversity of microhabitats used by small terrestrial wildlife throughout the year. Amphibians such as salamanders, garter snakes, small mammals, and bird species that frequent subcanopy areas can all be found in this habitat. These species, in turn, provide a prey-base for most predators in the study area. Coyote (*Canis latrans*), accipiters, raccoon, and Virginia opossum would all forage extensively in and around this habitat type.

Forest-shrub riparian wetlands are comprised of a mix of woody shrubs and trees associated with an herbaceous understory of hydrophytic species. The woody structure provides important habitat for wildlife associated with shorter trees. Trees in this habitat are typically smaller than those found in riparian gallery forest but the thick woody shrub/tree layer it forms produces important foraging and nesting habitat and cover for birds and small mammals. Many bird species spend the majority of their time in the understory of this habitat, including bushtit (*Psaltriparus minimus*), dark-eyed junco (*Junco hyemalis*), lesser goldfinch (*Spinus psaltria*), black-capped chickadee (*Poecile atricapillus*), spotted towhee (*Pipilo maculatus*), song sparrow (*Melospiza melodia*), western scrub jay (*Aphelocoma californica*), and golden crowned kinglet (*Regulus calendula*).

2.5.2 Wetland

Open water habitat, which includes riverine and ponded sites that are either perennial or seasonal, is very important for a myriad of wildlife species in the Refuge. Waterfowl assemblage changes throughout the year with migratory species visiting the Refuge for wintering, as a stopover during migration, or for breeding. During non-breeding months, open water sites provide important stopover or wintering habitat for various waterfowl including cackling goose, Canada goose (*Branta canadensis*), wood duck (*Aix sponsa*), gadwall (*Anas strepera*), American wigeon (*Anas americana*), mallard (*Anas platyrhynchos*), cinnamon teal (*Anas cyanoptera*), and bufflehead (*Bucephala albeola*). Other wildlife found in ponded sites include western painted turtle (*Chrysemys picta*), American coot (*Fulica americana*), pied-billed grebe (*Podilymbus podiceps*), purple martin, common yellowthroat (*Geothlypis trichas*), various swallow species, and occasionally beaver (*Castor canadensis*) and the invasive nutria (*Myocastor coypus*). Both mammal species are actively managed on the Refuge. Many species frequent open water habitat for foraging but principally reside in neighboring habitats such as wetland and/or riparian zones. Examples include piscivorous species such as belted kingfisher (*Megaceryle alcyon*), bald eagle (*Haliaeetus leucocephalus*), and osprey (*Pandion haliaetus*), as well as the common garter snake (*Thamnophis sirtalis*) and most amphibians.

Emergent wetland, which may or may not fringe open water, provides a moderate quality habitat for wildlife but is somewhat degraded on the Refuge by an extensive infestation of reed canary grass. The same wildlife species associated with open water habitat are often also found in emergent wetlands. Amphibians and waterfowl use the dense herbaceous vegetation for egg laying, and numerous other species use this habitat for foraging and for cover. Typical species include great blue heron (*Ardea herodias*), dabbling ducks, and Pacific chorus frog (*Pseudacris regilla*).

2.5.3 Grasslands

Maintained grassland is a managed landscape that is mowed, hayed, and/or grazed as part of the land management of the Refuge for waterfowl intended to support cackling geese and other wintering species. Grassland nesting birds and open-land mammals are the most common species in this habitat type. Grassland birds include western meadowlark (*Sturnella neglecta*), savannah sparrow (*Passerculus sandwichensis*), and American goldfinch (*Spinus tristis*). A prominent mammal of this habitat is the Columbian black-tailed deer (*Odocoileus hemionus columbianus*). Fossorial mammals would also be typical, including; voles, gophers, moles, and mice. Predators of these species would also be common, such as northern harrier (*Circus cyaneus*), barn owl (*Tyto alba*), American kestrel (*Falco sparverius*), long-tailed weasel (*Mustela frenata*), red fox (*Vulpes vulpes*), and coyote. As with other habitats, use varies with season, and maintained grassland is key to sustaining migratory birds, primarily waterfowl, as they fly north to their breeding grounds, or south to their wintering grounds.

2.5.4 Oak Woodland/Savanah

The oak woodlands habitat at the site provide upland refuge habitat that is used by amphibians, reptiles, birds and mammals. Oak trees provide upland refuge from heat, flooding, and predation. They also provide nesting, roosting, perching, and denning sites for many birds and mammals.

2.6 Water Quality

The Columbia River adjacent to the project area (Broughton Reach) is listed in the Washington Department of Ecology's (Ecology) 303d list for water temperature. A TMDL for total dissolved gas was approved by the EPA for this reach in 2002.

Gibbons Creek is listed on Ecology's 303d list for temperature. A TMDL for bacteria (fecal coliform) was approved by the EPA for Gibbons Creek in 2000.

Gibbons Creek is subject to increased water temperatures due to significant temperature problems in lower Campen Creek, a tributary to Gibbons Creek (Brandt et al. 2003). Over time, Campen Creek has undergone reduced shading and reduced summer flows that have contributed to elevated water temperatures (Ecology 2005). Also, ponds in the watershed may be contributing to elevated water temperatures; however, it has not been determined how much, if any, discharge contributes to the creek (Ecology 2005). Similarly, elevated summer water temperatures is the major water quality issue for Steigerwald Lake wetlands. This is largely due to its shallowness, with depths typically less than 5 feet. Another contributing factor is lack of seasonal water exchange with the Columbia River or other sources (e.g., Gibbons Creek).

The project will have a beneficial result on the water quality of the wetlands due to the increased water exchange with both the Columbia River and Gibbons Creek. Additionally, riparian vegetation will be planted along channels and wetland buffers throughout the project site. This vegetation will provide shade, thus cooling the water, as well as, provide habitat for wildlife species on the Refuge.

3 SITE ANALYSIS AND EVALUATION

3.1 Topographic Survey

Topographic and photogrammetric surveys of the site have been completed by Statewide Land Surveying (SWLS) and David C. Smith and Associates (DSA). Surveys were conducted beginning in July 2015, with supplemental surveys continuing through winter 2017. The purpose of the combined topographic and photogrammetric survey is to characterize the ground surface for use in hydraulic and other analyses, grading design, and quantity estimates. Photogrammetry was used to accurately characterize the large site more efficiently than a complete ground survey and more accurately than relying on LiDAR-based topography. The survey report is included in **Appendix B.**

The scope of the combined survey included:

- Ground survey
  - Control point network
  - Photo-reference grid points for photogrammetry
  - Gibbons Creek channel (BNSF railroad bridge to elevated canal)
  - Diversion structure
  - Elevated canal
  - Fish ladder
  - SR 14 road raise
- Photogrammetry
  - General site topography
  - Aerial orthophotos
- Datums and units
  - Horizontal datum: Washington State Plane Zone south, US survey feet
  - Vertical datum: NAVD88 in units of feet

3.2 Utilities

Utility locates for all work areas have not been completed at the time of publishing this report. Telecom, water, and power are currently delivered to the existing parking lot. The automatic gate on the parking lot access road and the irrigation system are connected to telecom and power services delivered from the west. These buried utilities are located just outside of the ROW south of SR 14. Water for irrigation is provided from a well east of the existing access road. The buried pipe is located just outside of the ROW, south of SR 14.

The west setback levee will cross the power and telecom utility lines. There is no anticipated impact to the utilities due to the construction of the setback levee.

Site specific utility locates were conducted for the geotechnical investigations along the proposed levee alignments. No utilities have been found. A comprehensive utility locate will be conducted for the 60% submittal. All located utilities will be included on the construction drawings (Appendix A).

3.3 Water Level Data

To calibrate and verify the hydrodynamic model of the Columbia River and Refuge floodplain, and to support hydraulic analysis of Gibbons Creek, a series of water level gages were installed. Two gages are in the Columbia River (CR-1 and CR-2), and two gages are in Gibbons Creek (GC-1 and GC-2). The location of each gage is included in **Figure 1-1**.

On September 8, 2015, one monitoring station was installed in Gibbons Creek. This station, GC-2, consists of a 10-foot-long section of ABS plastic pipe housing, containing a Solinst Levelogger sensor. The housing pipe was attached to a concrete wall on the downstream side of the Gibbons Creek diversion structure. A Levelogger was also installed inside the housing to collect barometric pressure data used for atmospheric pressure correction of the water level readings.

On September 16, 2015, two gages were installed in the Columbia River. CR-1 was installed along the bank of the Columbia River near River Mile 126.8. CR-1 consists of a 30-foot length of ABS plastic pipe housing, fixed to the bank using rebar staples and steel wire. The bank in this location is armored with rip rap, and some smaller stones were shifted to facilitate placement and attachment of the plastic housing pipe. Once the housing was fixed to the bank, smaller rip rap stones were placed next to and on top of the housing pipe to provide additional ballast. CR-2 was installed on a wooden pile in the Columbia River near Steamboat Landing at RM 125.2. CR-2 consists of a 10-foot-long section of ABS plastic pipe housing fixed to the wooden pile using brackets and lag screws.

On October 9, 2015, second gage was installed in Gibbons Creek, approximately 400 feet upstream of the SR 14 Bridge. This station, GC-1 consists of a 10-foot-long section of ABS plastic pipe housing, fixed to the bank using rebar staples, steel wire, and steel fence posts. A Levelogger sensor was installed inside the housing.

All Leveloggers were programmed to collect readings of water temperature and water level (via hydrostatic pressure) every 30 minutes. After each station was installed, the team used survey leveling to measure the elevation of the water surface at the station location. The time of the survey measurement corresponded to the nearest half hour, at a time when the Levelogger would be collecting a water depth reading. This survey data is used to calculate the water surface elevation of each water depth record. The stations are intended to collect data beginning with the current low-flow conditions and continue through the winter and spring flooding seasons. The water level data will be retrieved and processed to be used for model calibration and verification.

3.4 Geomorphic Analysis

Geomorphic assessments of the Columbia River and Gibbons Creek in the vicinity of the Refuge were conducted to describe the historic and current processes through which these systems have shaped landforms in the project vicinity. This understanding provides context and direction for development of the restoration strategies. Site geomorphology was analyzed during the feasibility phase and preliminary design phases of the project which included Gibbons Creek (Estuary Partnership 2015; W2r 2017), and the Columbia River in the vicinity of the Refuge (ESA 2015a). The following sections summarize these geomorphic assessments, which are included in **Appendix C**.

3.4.1 Columbia River

The Refuge geomorphology was historically dominated by Columbia River fluvial processes. Gibbons Creek fluvial processes are dwarfed by those of the much larger Columbia River. Anthropogenic changes have greatly altered the natural water and sediment regime of the site. Currently, infrastructure including the flood damage reduction levees substantially limits natural geomorphic processes, and the altered hydrology of the river also contributes to impaired floodplain functions.

Major geomorphic landforms that developed prior to the levee system are still visible on the site and provide evidence of the historic geomorphic processes that occurred. These major landforms are mapped in **Figure 3-1**; letters refer to the key geomorphic features. **Figure 3-2** provides a cross-section through the refuge with major geomorphic landforms labelled. Each of the major fluvial geomorphic landforms at the site is interrelated and includes:

- The terrace (A), an inactive floodplain, flanks the valley wall and generally forms the northern boundary of the site. Floodplain deposition processes gradually form natural levees (B), which form adjacent to the channel on the floodplain.
- The backswamp/depressional wetland (C) is then formed between the natural levees and the terrace as the natural levees impede floodplain drainage. Natural channel migration forms successive natural levees, roughly paralleling the contour of the point bar and progressively building out from it over time, which together form the bar and scroll complex (D).
- When the natural levees are breached, floodwaters deposit coarse sediment inside of the natural levees, thus creating crevasse splays (E) across the bar and scroll complex. The crevasse splays exhibit northwesterly-facing somewhat elongate ridges of higher and more variable topography than the surrounding floodplain bar and scroll.
- Tributary creeks flow down the valley wall, onto the terrace, and then the floodplain, depositing an alluvial fan (F) at the break in slope as they drop their coarse sediment load as slope and stream power diminishes. These streams then flow into lakes in the backswamp and/or flow parallel to the main river until they find a topographic break in the natural levees, which enables them to join the main river.

The location of the new Gibbons Creek confluence with the Columbia River is constrained within the Refuge. It is not possible to restore connectivity of the site at its historic locations because the Port's Industrial Park has been constructed at this location (west end of the floodplain). The restored Gibbons Creek connection is located within a large side channel of the Columbia River adjacent to Reed Island (Reed Island Channel), which is on the inside of the Columbia River meander bend. The inside of meander bends can be prone to sedimentation, which may affect the Gibbons Creek channel.

Reed Island has migrated downstream and lengthened since the 1901, and Gary Island (in the southwest corner of **Figure 3-1**) has changed dramatically. The Refuge shoreline does not show dramatic changes since the 1901 T-map; it appears to be considerably more stable than the neighboring islands.

The following key actions will help restore the pre-disturbance geomorphic processes at the site:

- Allow the perennial drainage of Gibbons Creek through Steigerwald Lake and the Columbia under low Columbia River flows and backwatering of Gibbons Creek during the spring freshet and under Columbia River high flows;
- Remove infrastructure constraints from the Gibbons Creek that will allow the creek to move dynamically across its alluvial fan; and
- Allow Columbia River connections through the natural fluvial levee at multiple locations and at connection frequencies similar to those that occurred historically.

3.4.2 Gibbons Creek

In the upper portions of its watershed, Gibbons Creek and its tributaries flow through relatively steep, incised valleys as they flow down the northern slope of the Columbia River Gorge. The average channel gradient in the watershed is 9.7 percent, and the gradient decreases considerably as the creek reaches the valley floor, near the BNSF crossing. Along the valley floor the channel slope reduces to less than 1 percent. Gibbons Creek was channelized and realigned (south of the BNSF railroad crossing) to cross SR 14, slightly east from its original location. The channel between the railroad and SR 14 is incised.

The transition zone between the northern slope of the Columbia River Gorge and the valley floor is a depositional zone resulting in the formation of the alluvial fan shown in **Figure 1-1** and **Figure 3-1**. Currently Gibbons Creek is locked into its present location by the SR 14 bridge and diversion structure. These structures prevent the creek from interacting naturally with its alluvial fan.

The hydraulic constriction of the diversion weir at the head of the elevated canal results in a 200-linear-foot (12,000 square feet) portion of the Gibbons Creek channel (between the diversion structure and SR 14) requiring routine sediment dredging. This dredging is essential to maintain channel capacity, reduce overflows into Refuge wetlands, reduce stranding of fish and aquatic organisms, and reduce flood impacts to the SR 14 bridge and upstream infrastructure. Records maintained by USFWS show that on average dredging is required two out of every three years (USFWS 2011). Between 1995 and 2011, USFWS removed a total of over 11,600 cubic yards (7.2 acre-feet) of material from this portion of Gibbons Creek. During this time, additional bedload was transported through this area into the overflow channel and is not accounted for. Removal of the diversion structure will allow this material to transport downstream and a small amount of channel degradation can be expected; dredging will not be required.

Potential channel stability of the restored channel (proposed conditions) was analyzed in a hydraulic and sediment transport modeling study using HEC-RAS (W2r 2017). This analysis indicates that the restoration reach immediately upstream and downstream of SR 14, with a longitudinal channel bed slope of approximately 1.2%, does not show a tendency to either erode or aggrade over the long term. This bed slope includes lowering the channel bottom by approximately 1 to 2 feet relative to existing conditions below the SR 14 bridge, where survey data from 2010 and 2015 suggests that the channel has aggraded several feet over this time (as a result of the diversion structure).

3.5 Summary of Hydrology and Hydraulic Analyses

Various hydrologic and hydraulic analyses (Gibbons Creek and the Columbia River) have been completed to assess potential project impacts. To facilitate the USACE review, results and findings of these analyses are summarized in one comprehensive project Hydrologic Risk Report. This report is included in Appendix D with the individual analyses provided as attachments. The completed hydrologic and hydraulic analyses are listed below:

- **Hydrodynamic Modeling**: two-dimensional hydrodynamic model assessment of the Columbia River to assess the impacts of restoration on hydrodynamics (flood and lower water levels and inundation extents, velocities, bed shear stress, circulation patterns, habitat conditions, breach channel hydraulics) (original memo dated July 31, 2015, updated October 9).
    - Computer model: Delft3D Hydromorphodynamics Module, Version 3.15 (2014).
    - The Columbia River Hydrodynamic Modeling memo is presented in Appendix D Attachment 1 (D-1).
- **Gibbons Creek Hydraulic and Sediment Transport Analyses**: hydraulic modeling of Gibbons Creek to compare existing and proposed water surface profiles and inundation extents/depths in the creek to ensure no impacts to adjacent landowners and to support creek design. Sediment transport modeling to ensure sediment moving through the watershed will not excessively deposit or scour, negatively affecting flood water levels or adjacent infrastructure.
    - Computer model: HEC-RAS Version 4.1 (mobile bed sediment transport simulations) and HEC-RAS 5.0 (unsteady flow and flood mapping analysis – version 5.0.3 for improved RASmapper functions).
    - The Gibbons Creek Hydraulic and Sediment Transport Analyses memo is presented in Appendix D Attachment 2 (D-2).
- **Interior Drainage Analysis**: Interior drainage analyses to evaluate the hydraulic effects of changing site drainage patterns within the proposed levee system. Analyses of the interior drainage system associated with the west and east levees have been conducted and are summarized in Section 4.10.
    - Computer model: HEC-RAS Version 5.0.
    - The Interior Drainage Analysis memo is presented in Appendix D Attachment 3 (D-3).
- **Wind-Wave Analysis**: wind-wave analysis of erosion potential within the refuge (SR 14 roadway and levee embankments) to support design of vegetated levee and roadway overbuild sections, i.e., wave-break berms.
    - Computer model: Delft3D SWAN Module, Version 4.1.
    - The Wind-Wave Analysis memo is presented in Appendix D Attachment 4 (D-4).
- **Flood Risk Analysis**: flood risk analysis using HEC Flood Damage Reduction Analysis (HEC-FDA) to characterize flood risks and verify that the existing levee meets USACE conditional non-

exceedance criteria based on the combined probability water surface profiles in the Columbia River and Gibbons Creek flood water levels.

- Computer model: HEC-FDA Version 1.4.1.
- The Flood Risk Analysis memo is presented in Appendix D Attachment 5 (D-5).

3.5.1 Columbia River Water Levels

The fourteen dams on the Columbia River mainstem and hundreds of dams on the Columbia's upstream tributaries greatly influence river flows at the Refuge. Construction of the large mainstem dams including Bonneville and Grand Coulee Dams began in the 1930s, with the last of the mainstem dams completed in the 1980s. These dams reduce flood flows, particularly during the spring freshet, between March and June. In addition, dams result in increased low-flows between September and December. The overall effect is dampening and moderating the hydrograph year-round. The river's flow is now roughly evenly split between spring/summer (April through September) and autumn/winter (October through March) (National Research Council 2004).

Table 3-1 summarizes key water surface elevations at the site, pertaining both to flood recurrence milestones and elevations that would result in flooding or damage of infrastructure. Under the current operation of the Columbia River hydropower system, Columbia River stages are dynamic on both a seasonal and inter-annual scale; water levels vary dramatically from typical dry season stages to much higher stages that occur during 50% annual chance exceedance (ACE, i.e., 2-year) events and higher floods. The original FDR levee design flood was 41.46 feet NAVD88 (USACE 1964). It is important to note that the design of the new setback levees is not based on an annual chance exceedance level, but on the levee crest elevation profile from the original levee design drawings as described in Section 4.9.

Table 3-1 Summary of Columbia River Water Levels and Reference Land Elevations near Steigerwald NWR.

Feature / Columbia River Water Level	Elevation at RM 125.5 [West Levee] (Feet NAVD88)	*Elevation at RM 125.5 [West Levee] (Feet NAVD88)	Elevation at RM 127.7 [East Levee] (Feet NAVD88)	Source and Notes
Levee Crest Elevations	45.7	45.7	46.3	USACE 1989; Cornforth 2012
0.2% ACE[1] Event	38.5	37.4	38.8	USACE 2007**; USACE 1991
SR 14 Low Point	35.2	NA / No Change	NA	SWLS 2017; low point is near Refuge parking lot
Regulatory Base Flood Elevation (1% WSE[2])	35.5	NA	36.0	FEMA FIS 2012[ǂ]
1% ACE Event	35.1	32.9	35.6	USACE 2007
2% ACE Event	33.8	34.3	34.3	USACE 2007

Feature / Columbia River Water Level	Elevation at RM 125.5 [West Levee] (Feet NAVD88)	*Elevation at RM 125.5 [West Levee] (Feet NAVD88)	Elevation at RM 127.7 [East Levee] (Feet NAVD88)	Source and Notes
50% ACE Event	26.9	24.7	27.1	USACE 2007
Columbia R. Ordinary High Water Level (OHW)	26.6	NA	26.6	Regulatory, based on USACE 2007 (Wetland Delineation Rept.; W2r 2017)
50% ACE Water Level (for Habitat Area Evaluation)	23.7	NA	23.7	Estuary Partnership 2014 (approx. 2-year water level)
Levee Interior 1% ACE Event	22.4	22.4	22.4	USACE 2012a, FEMA 2000

*Water surface elevations in this column are winter only elevations (USACE 2007).
[1]Annual Chance Exceedance; [2]Water Surface Elevation
**Regulated (post 1976 conditions – 14 dams, 39.7 MAF storage) flood frequency profiles based on storage-frequency relationships, unsteady flow model (DWOPER) and engineering judgment. River miles correspond to NWRBC (June 1962).
ǂFEMA FIS Regulatory WSE taken from Table 6 Floodway Data. Profiles differ by approx. (-0.5 feet).

3.5.2 Gibbons Creek Peak Flows

Peak flow estimates will be used to design critical elements of the restoration such as the Gibbons Creek floodwall. Peak flows in Gibbons Creek were initially documented during the initial feasibility phase (ESA 2014b) and later updated using peak flows of nearby gaged streams and drainage basin area-scaling in order to improve estimates (ESA 2015c). Most recently, Gibbons Creek hydrology was re-evaluated during interior drainage analysis of the Port's drainage and pump system using the HEC-HMS watershed model (WEST 2017). Results of the re-evaluated hydrology analysis are shown in Table 3-2 below.

Table 3-2 Refined Gibbons Creek Base and Peak Flow Estimates.

Flow Parameter / Peak Flow (Annual Chance Exceedance)	Flow (cfs)	Reference
Estimated Base Flow	< 10	Field observations (various dates summer & fall 2015 & 2016)
67% ACE (approx. 1.5-yr flow)	230	Engineering estimate
50% ACE	310	WEST 2017
20% ACE	520	WEST 2017
10% ACE	660	WEST 2017
2% ACE	990	WEST 2017

Flow Parameter / Peak Flow (Annual Chance Exceedance)	Flow (cfs)	Reference
1% ACE	1,130	WEST 2017
0.2% ACE	1,450	WEST 2017

3.5.3 Gibbons Creek Hydraulic and Sediment Transport Analyses

Sediment Transport Findings

Sediment transport modeling was conducted to evaluate transport conditions in the lower Gibbons Creek watershed and to identify potential regions of adverse deposition and/or scour – which could negatively affect flood water levels or adjacent infrastructure. Analysis was also intended to provide assurance that the SR 14 bridge will not cause deposition that will affect the design of the levee/floodwall. Analysis also demonstrated if sediment maintenance downstream of SR 14 will be required under the proposed conditions. Further, the sediment model was used to develop a reasonable long-term (i.e., dynamically stable) bed profile and channel condition for use in the unsteady flow analysis (described in the preceding section). As a note, the sediment transport analysis was completed first; then, using the long-term bed profile, unsteady flow hydraulics were evaluated.

Results of the sediment transport analysis are described in detail in Appendix D-2 (Gibbons Creek Hydraulic and Sediment Transport Report). Primary findings of the analysis include that it is feasible to restore Gibbons Creek within its alluvial fan and within the general physical constraints of the proposed floodwall, the SR 14 bridge, and the downstream hydraulic controls of the Columbia River. Modeling results showed the following:

- The restored creek geometry (cross sections and longitudinal profile) did not negatively affect the sediment transport potential (scour or deposition) upstream of the restoration limits, as indicated by similar magnitudes and trends (aggradation or degradation) in sediment transport between existing and proposed conditions upstream of the BNSF railway bridge.
- The restored creek exhibited dynamically-stable transport characteristics. Periodic, local scour and erosion did occur over the simulations, but bed changes tended to self-adjust or stabilize later during the simulation period.
- The restored creek channel passed sediment through the SR 14 bridge (in part due to lowering the bed elevation / increasing the longitudinal slope) without showing potential for deposition below or upstream of the bridge. Rather, model scenarios indicated scour below the bridge; consequently, scour countermeasures for the banks and bed were assumed in the model (maximum scour was limited below the bridge). Scour countermeasures (roughened rock toe and cobble riffles) were also added to the revised 30% design.
- The restored creek also deposits bedload along its lower alluvial fan approximately 500 feet or more downstream of the SR 14 bridge. This deposition does not appear to negatively flood water levels near SR 14.

Check of Model Reasonableness (Replication of Observed Deposition)
Simulation of existing Gibbons Creek conditions was conducted to check reasonableness of sediment transport results. In general, existing conditions simulations showed a general tendency for deposition downstream and upstream of the SR 14 bridge, and the range in deposition varied from approximate 0.5 to 2.0 feet. At the SR 14 bridge, the deposition at the bridge is approximately 1.9 feet. This is consistent with winter storm observations and documented sediment maintenance records kept by USFWS.

Inundation Mapping
Gibbons Creek and Columbia River flood extents were mapped under various annual chance exceedance events and are presented in the Hydraulic and Sediment Transport Analysis Report (Appendix D-2). Under restored conditions, water levels in Gibbons Creek were generally lower than existing water levels, except near SR 14 during backwatering of the Columbia River at extreme stages. The SR14 bridge passes flows up to and including the coincident (combined winter Columbia River stage and Gibbons Creek winter flow) 1% ACE event. However, shallow (less than 6 inches) overtopping of the SR 14 bridge was observed at the coincident 0.2% ACE event under restored conditions. Overtopping occurs because the coincident 0.2% ACE event includes a Columbia River WSE of 37.4 feet NAVD88, which is less than 1-foot below the SR 14 bridge deck elevation. During the 0.2% ACE overtopping event, the risk of significant bridge and/or road erosion is relatively minor because water levels upstream and downstream of the road are nearly equal due to backwatering conditions of the Columbia River.

The vacant field east of Gibbons Creek and north of SR14 (owned by USFWS), provides approximately 100 acre-feet of overflow storage during storm events. Under restored conditions, the creek overtops its banks under extreme flood events (only the 0.2% ACE event), spills into this storage area, and eventually drains through two existing 24-inch culverts under SR 14. The WSE in the overflow storage area during a 0.2% ACE event is 33.25 feet NAVD88 and utilizes 17 acre-feet of the total storage (100 acre-feet). These two culverts will be retrofitted with backflow valves (flap gates) to prevent the Columbia River from 'backwatering' through the culverts into the field storage area.

The private properties west of Gibbons Creek are not inundated under any restored creek water levels including the extreme 0.2% ACE event because the new floodwall prevents inundation on the west side of the creek. This is not the case under existing conditions, during which the 4% through the 0.2% ACE events inundate these properties. Thus, a significant benefit of creek restoration is reduced inundation risk for the private properties west of Gibbons Creek.

3.6 FEMA Floodplain Analysis

Due to the proposed modifications to the levee system and the resultant change in the Columbia River floodplain boundaries, a Conditional Letter of Map Revision (CLOMR) application for the Columbia River will be required by Federal Emergency Management Agency (FEMA). The Columbia River flood profiles and the Columbia River floodplain mapping in the FEMA Flood Insurance Study (FIS) were derived directly from the USACE combined stage-frequency curves. The stage-discharge relationship on the Columbia River is influenced both by ocean tides and backwater from the Willamette River; therefore, flood frequencies are more reliably determined for river stages than for river discharges (FEMA 2012). For the Columbia River, the HEC-2 program was only used for the floodway determination. Flood profiles were derived directly from the combined stage-frequency curves. Per FEMA (2012), the discharges used in floodway computations for the Columbia River were correlated, based on data at USGS gage No. 14105700 (established in 1857) at The Dalles, to yield water-surface profiles similar to those prepared using the FEMA (2012) combined stage-frequency curves. On the FEMA Flood Insurance Rate Maps (FIRM), the Columbia River in the project vicinity is mapped as Zone AE (base flood elevations determined), while the area behind the Washougal Flood Damage Reduction (FDR) levees is variously mapped as shown in **Figure 3-3**. No FEMA floodplain mapping exists for flooding from Gibbons Creek, and the area behind the Washougal FDR levees has an interior drainage system.

The CLOMR analysis and mapping also shall include new mapping of Gibbons Creek, which is not currently a part of the FEMA flood study and maps. This need for a CLOMR will require coordination between the project team, FEMA Region X, FEMA Headquarters, Clark County, and the City regarding the CLOMR process. Ongoing coordination with these entities will occur throughout the FEMA CLOMR and local floodplain permitting process. Following FEMA guidance to date, the current hydraulic model of the Columbia River will be revised to conduct the floodway encroachment analysis. The current/updated topographic/bathymetric survey data of the Columbia River will be used for the floodway modeling. The CLOMR will be based on existing Columbia River base flood and 500-year water surface elevation profiles (defined by the USACE combined probability flood profiles) and the currently available LiDAR/bathymetry data. The Gibbons Creek flood mapping will be based on unsteady flow hydraulic analysis of the creek. The base flood profiles will be remapped across the post project topography.

The following mapping, all at the same scale (scale will be sufficient to show how new mapping ties into the effective FIRM map), will be created:

- Effective FIRM Map.
- Existing Floodplain Map based on FEMA (2012) stage-frequency curves and Watershed Sciences (2010) topographic data combined with the existing project survey topographic data (Statewide Land Surveying Incorporated, 2015). Note: changes in topography since the Effective FIRM Map was created and differences in topography data sources will cause some discrepancies between the Effective FIRM Map and the Existing Floodplain Map.
- Existing Conditions or Pre-Project Conditions HEC-RAS Floodway Map. Note: changes in topography since the effective FIRM was created will cause some discrepancies between the Existing Conditions or Pre-Project Conditions Floodway mapping and the effective FIRM floodway mapping.
- Revised or Post-Project Conditions Floodplain Map (including 1% Flood Elevation and 0.2% Flood Elevation).
- Annotated FIRM Panel, which will include the 1% Flood Elevation, 0.2% Flood Elevation, and Floodway, which will need to tie-in with the upstream and downstream water-surface elevations on the effective FIRM within one-half foot.

The necessary project narrative, FEMA forms (including levee/floodwall documentation for demonstrating how the project levees will meet National Flood Insurance Program (NFIP) Regulation 44 CFR Ch. 1, Section 65.10 (Section 65.10) requirements), design plans, evaluation of alternatives, etc. for a complete CLOMR submittal package to FEMA will be provided. Coordination with FEMA to facilitate

FEMA's approval of the CLOMR will be performed. After the project is constructed, a Letter of Map Revision (LOMR) application will be submitted to FEMA.

FEMA has deemed that the Washougal FDR levees currently meet the requirements of Section 65.10. The CLOMR application will detail how the Washougal FDR levee will continue to be in full compliance with Section 65.10 during project construction. The construction of the setback levees will use material from the existing levee breaches within one low water season. Engineering analysis in the CLOMR application will also document how the new setback levees and new closure structure, once constructed, will meet the Section 65.10 requirements. The CLOMR application will be approved by FEMA before the project is constructed.

After construction is complete, the LOMR application will be completed, which will include documentation of as-built flood hazard conditions and engineering analyses documenting how the new levees meet the current Section 65.10 requirements. After FEMA approves the LOMR, the flood maps will be updated.

3.7 Project Risk

Risks associated with the restoration include potential adverse effects on adjacent properties and infrastructure. Adjacent properties and infrastructure potentially affected by site restoration include:

- BNSF railway located adjacent to the northern project boundary.
- WSDOT SR 14 roadway and embankment which bisects the project area to the north.
- The Port industrial development located adjacent to the west setback levee.
- Private landowners north of SR 14 and west of Gibbons Creek.
- Private landowner east of the east setback levee.
- USFWS property within the refuge.
- The City of Camas and Washougal future wellfield.

The intent of the proposed restoration is to provide a consistent level of flood risk reduction as authorized in the FDR Project. The restoration project will build setback levees to reduce exterior (Columbia River) flood risks, and it will reduce interior flood risk to the Port, WSDOT, the City, and private properties and infrastructure by removing Gibbons Creek from the interior of the levee system and removing the diversion structure and elevated canal, increasing the hydraulic capacity of the SR 14 bridge. The proposed setback levees are designed to match the existing levee crest elevation. The new levee system will include a floodwall/berm along the west bank of Gibbons Creek to maintain flood protection of properties north of SR 14.

The possible impacts of the proposed restoration on these infrastructure and properties were assessed and presented in the Hydrologic and Hydraulic Summary Report (Appendix D). Modifications to the design to address or mitigate impacts are outlined in Section 4.5 (Infrastructure Considerations) below.

The project will undergo review and approval by BPA, USACE, the Port, WSDOT, and USFWS. The project will also require approval through Section 408 of the Rivers and Harbors act to ensure that alteration of the authorized federal projects will not be injurious to the public interest and will not impair the usefulness of the projects.

4 DESIGN

Site restoration will include removing 2.2 miles of the existing levee, constructing two new setback levees and associated structures, removing the Gibbons Creek diversion/canal infrastructure, expanding habitat areas, various recreation and public access components, woody debris placement, and revegetation. These measures are shown in **Figure 1-2**. The following report sections describe the restoration objectives, climate change adaptability, technical analysis, design criteria, assumptions, and constraints, and HIP III conservation measures. The 30% construction drawings are included in **Appendix A.**

4.1 Restoration Goals and Objectives

The goals and objectives for Refuge restoration were originally documented in the Conceptual Design Report (ESA 2015b) and are repeated below for convenience.

The overall goals for the restoration at the Refuge are as follows:

- Maintain or reduce flood risk for all affected infrastructure.
- Restore floodplain connectivity and physical processes to historic (pre-disturbance) conditions to the greatest extent possible.
- Provide access to restored habitats for native fish and wildlife species.
- Improve the habitat capacity of restored channels, wetlands, and the adjacent riparian and upland regions.
- Increase and diversify recreation opportunities.

These goals are expressed through the following objectives:

- Reconnecting Gibbons Creek to the Refuge, and reconnecting the Refuge to the Columbia River.
- Maintaining the existing level of Columbia River flood risk reduction.
- Significantly decreasing the level of Gibbons Creek flood risk.
- Providing unimpeded fish access and passage between Gibbons Creek, the Refuge, and the Columbia River for all native species and life stages.
- Improving the quality, diversity, and function of aquatic and riparian habitats, particularly
    - off-channel refugia for out migrating salmonids (rearing and over-wintering habitats for multiple up-river and Lower Columbia River ESUs); and
    - spawning habitats for Lower Columbia River coho salmon, steelhead, lamprey, and potentially chum salmon.
- Restore habitats with resiliency to the effects of climate change, including rising estuarine water levels and higher variability in Gibbons Creek hydrology.
- Increase the length and diversity of hiking trails and associated infrastructure.

Specific restoration actions towards these objectives include:

- Removing and breaching the Columbia River levee that separates the Refuge from the river.
- Removing the Gibbons Creek water control structures and elevated canal that impair sediment transport, fish passage, and hydraulic and habitat conditions on the creek's alluvial fan and on its deltaic connection with the river.
- Re-establishing self-sustaining emergent wetland, herbaceous wetland, and riparian native plant communities.
- Increasing wood habitat structure densities to those found in reference streams and wetlands.
- Increasing the spatial diversity of the Refuge's thermal regime, including the location, size, and extent of cold-water refugia.
- Expanding emergent and herbaceous wetland habitats by encouraging beaver use of the site.
- Considering climate change impacts through the above actions and specific design measures.
- Designing levee breach invert elevations that accommodate potential changes to the Columbia River hydrograph in combination with expected sea level rise and over the project lifespan (approximately 50 to 75 years).
- Creating floodplain habitats that transition to both higher and lower elevations in response to changing Columbia River hydrographs.
- Designing floodplain channels that accommodate lower flows and depths associated with decreases in spring and summer base flows as well as accommodating higher flows and depths associated with increases in peak flows in the restored Gibbons Creek.
- Constructing setback levees that match the height of existing levees and meet USACE design standards.
- Restoring the design/as-built conditions of Gibbons Creek below the SR 14 bridge.
- Increasing the length of hiking trails at the Refuge by 0.5 miles, installing two bridges to cross floodplain channels, meandering the hiking trail through restored riparian forests and wetlands, and enhancing interpretative features.

4.2 Climate Change Adaptability

Future projected climate change was incorporated into the planning and design of the Steigerwald project following USACE ECB 2016-25 (USACE 2016) and USACE ETL 100-2-1 (USACE 2014b). Additionally, the USACE Framework for Incorporating Climate Change and Building Resiliency into Restoration Planning: Lower Columbia River Estuary and Case Study (USACE 2012b and 2015) was reviewed for guidance. The USACE (2012b) report predicts quantifiable impacts of climate change in the Lower Columbia River Estuary that include: (1) shifts in hydrology caused by warmer future temperatures, and (2) sea level change at the mouth of the Columba River caused by an expected rise in ocean levels.

Expected shifts in hydrology will result in increases in fall, winter, and spring precipitation and reductions in summer precipitation. Heavier rainfall events are predicted, increasing peak storm flows. Additionally, less precipitation is projected to fall as snow, reducing snowpack, which will result in an earlier, yet reduced freshet peak and reductions in summer base flow conditions. Based on USACE projections (2012b), sea level rise would propagate up the Columbia River and result in a rise at the Steigerwald project site of approximately 0.55 feet by 2064 and 1.60 feet by 2100.

The USACE (2012b) identifies that estuary restoration projects face climate change risk to two main sets of features: (1) habitat that the project is trying to restore and (2) on-site and off-site infrastructure and surrounding land uses. Both risks should be addressed in the project design.

The USACE (USACE 2012b) also identifies example potential stressors, sensitivities, and adaptation measures for the Lower Columbia River estuary. The Steigerwald project was reviewed and analyzed with respect to the limiting factors and climate change vulnerabilities and climate change projection information provided within the USACE framework. As a result, the following potential climate-influenced site stressors and impacts/sensitivities were identified at Steigerwald:

1. Increases in water levels due to sea level rise will likely influence the establishment of desired plant communities.
2. Higher ambient air and water temperatures would increase stress on fish and other aquatic organisms and vegetation, shifting plant community composition.
3. Shifting river flow timing could affect juvenile salmonid rearing needs.

Climate change adaptability measures being considered in the design of both the habitat features and the protection of on-site and off-site infrastructure and land use features of the Steigerwald Project are as follows.

Habitat Features:

- Grading the floodplain with variable topography to enhance inundation in some areas and transition to higher and drier elevations in other areas for improved plant diversity and adaptability.
- Installing wood habitat structures that encourage scour of deep pools for shaded, cold water refugia for overwintering salmonids and other aquatic species.
- Restoring a robust, native plant species composition that adapts to variable hydrologic and groundwater regimes, especially drought conditions.

Infrastructure and Land Use Features:

- Setback levee design to accommodate future increases in levee height if required in 50 or 100-years of projected sea level rise.
- Gibbons Creek channel and floodwall design is based off peak flows that were increased by roughly 20 percent to account for projected changes in flood magnitude caused by climate change. This increase is based on studies conducted by the Climate Impacts Group at the University of Washington (CIG 2013), as mentioned in Chapter 3.6.2.
- Floodplain connection channel invert elevations that accommodate expected sea level rise over expected project lifespan (approximately 50 to 75 years).
- Creek channels that adapt or self-adjust to and accommodate both higher peak flows and lower spring and summer base flows. For example, the cross-section design has a shallow v-bottom shape that focuses low-flows and maximizes depths (instream habitat) during dry periods which are likely to become drier as a result of climate change.

These climate change resiliency measures are described further in the following chapters and incorporated into the project design criteria to reduce future climate change risk and uncertainty.

4.3 Floodplain Channels

Hydraulic connectivity between the Columbia River and the Refuge would be restored primarily through four floodplain channels. The channels will be excavated through the natural fluvial levee (the entirety of the Port's existing levee will be removed between the two new setback levees) and into the interior of the Refuge to varying extents. Each channel is intended to be self-sustaining and based on stream simulation design principals that consider hydraulic, sediment, and biological transport processes and functions.

The design (dimension and connection elevation) of each channel varies with the intended function and purpose. The four channels are described below and illustrated on **Figure 1-2**. Channel breach geometry is highlighted in **Table 4-1** with breach location shown in the construction drawings in **Appendix A**.

Table 4-1 Floodplain Channel Geometry.

Floodplain Channel/ Connection Type	Connection Elevation (Feet NAVD88)	Columbia River Level (Feet NAVD88)	Bottom Width (Feet)	Slope Through Channel (%)	Slope at River Connection (%)	Total Length (Feet)	Notes
Channel 1 High Flow	23.0	10.0	15	Flat	2.0-3.5	3,400	Restored crevasse splay (existing Gibbons Cr. Channel)
Channel 2 Intermediate Flow	17.0	10.0	10	Flat	0.5–1.0	4,480	Connected during typical winter conditions
Channel 3 Gibbons Creek	14.5	8-10	15	Flat	1.0-2.0	5,000	Primary, perennial connection
Channel 4 High Flow	23.0	20.0	10	Flat	2.0-3.5	3,900	Upstream-most connection

4.3.1 Channel 3 (Gibbons Creek)

The primary floodplain connection is Channel 3. This channel will accommodate Gibbons Creek flows during periods when the Columbia River does not backwater into the Refuge. The channel is designed to accommodate natural geomorphic changes in planform and geometry due to variations in:

- Rainfall-runoff hydrology of Gibbons Creek watershed and the Refuge;
- Seasonal sand bedload transport conditions in the Columbia River; and
- Vegetation establishing within the floodplain channels and the adjacent sand flats.

As described in the geomorphic analysis, this connection channel is located at the inside of a Columbia River side channel meander bend which is an area that can be prone to sedimentation. Sedimentation of the banks of the Columbia is a natural process. Gibbons Creek is a perennial creek with significant typical summer and winter flows. The morphology of the connection channel will be a result of the interaction of these two processes. The channel is not expected to become permanently cut off or otherwise adversely effected because:

- The hydrology and hydraulics of the creek are sufficient to sustain an opening in the relatively erodible sandy banks of the river. At a 2 percent slope, the base flow (10cfs) would have a shear stress almost 6 times higher than the critical shear stress of the compacted silts that make up the floodplain and will help maintain the channel outlet.
- Sediment transport dynamics in the Columbia downstream of Bonneville dam are relatively low due to the impaired sediment supply from the dam as well as the muted hydrology associated with dam operations.
- We expect the connection channel to be perennial, dynamic, and fish passable—similar to the morphology of Lawton Creek, the nearby Thousand Acres connection channel, and side channel habitats within the restored Sandy River Delta.

This Gibbons Creek channel has the lowest thalweg (invert) elevation of 14.5 feet NAVD88. This elevation is intended to replicate existing inundation depths and extents in Steigerwald and Straub Lakes during dry seasons, when Gibbons Creek flows into these Refuge depressions, through this channel, and to the Columbia River. Channel 3 will also accommodate wide ranges in creek and floodplain processes: perennial drainage of Gibbons Creek under low Columbia River flows (stages), and backwatering (inflow/outflow) from the river during the spring freshet and winter flow events. The channel has a 120-feet-wide floodplain, and a narrower 15-foot-wide inset channel at non-backwatered conditions. The connection reach is a shallower gradient channel designed at a slope of less than half a percent through most of this reach. The channel gradient increases at the confluence, with the final 600 feet sloping to the river at a slope of less than two percent.

4.3.2 High and Intermediate-Flow Connections

Channels 1 and 4 are high flow channels with a connection elevation of 23 feet NAVD88 located along the northern side of the natural levee (see sheet C1.0, **Appendix A**). These channels provide additional floodplain connection at flow events on the order of the 2-year or greater. Channel 1 primarily consists of the existing Gibbons Creek channel along Redtail Lake with a relatively small amount of grading at the breach to cross the natural levee. Channel 4 primarily consists of existing low floodplain topography from Straub Lake, sloping towards the Lake to the maximum channel elevation (23 feet NAVD88). From this high point, the channel slopes towards the Columbia River requiring channel grading through the final 1,200 feet of natural levee. Most of Channel 4 is gently sloped (less than 1 percent) into the project site.

Channel 2 provides an intermediate connection to the Columbia River with a maximum channel elevation of 17 feet NAVD88 located at Steigerwald Lake. This lower elevation will provide for an additional outlet for site drainage during intermediate Columbia River stages. The proposed channel alignment crosses the Scaup Pond creating a free-flowing hydrologic connection between the pond and

Steigerwald Lake. One result of this approach may be reduced seasonal inundation in the Scaup Pond area.

4.3.3 In-Channel Habitat

To add complexity to the in-channel habitat of the floodplain channels, the following elements are incorporated in the design:

- Wood habitat structures along the channel banks. In locations such as Channel 3 (Gibbons Creek perennial channel), the wood structures are intended to serve as passive beaver dam analog structures to encourage beaver dam construction;
- Live stake planting to increase channel bank stability, shading, organic inputs, and future wood recruitment.

These channel features all cross the Columbia River riparian zone and have riparian zones of their own and, therefore, will be planted with riparian, willow scrub, and native seed as appropriate. Proposed revegetation is discussed in more detail in Section 4.14. Planting is intended to create suitable beaver habitat and encourage dam building which would further improve the quantity and quality of off-channel fish and wildlife habitat.

4.4 Gibbons Creek

Restoration of the northern portion of Gibbons Creek involves removing the existing diversion structure and elevated canal and re-aligning portions of the creek. This approach would allow the stream to migrate across its historic alluvial fan once-again, and it would eliminate the need for removal of creek deposits at the diversion (Estuary Partnership 2013; USFWS 2013a). Gibbons Creek will flow through Steigerwald Lake and out through Channel 3, having a direct connection to the Columbia River, thereby providing unimpeded fish passage. The new Gibbons Creek channel is designed to meet the following design objectives:

- Fish passage – Provide fish passage for all salmonid life stages at the full range of hydrologic conditions.
- Habitat – Improve in-stream habitat quality through the re-establishment of natural processes and active restoration, e.g., riparian plantings, placement of large wood, and restored floodplain connectivity.
- Channel stability - Provide stable channel design in the vicinity of existing and proposed infrastructure.
- Sedimentation - Channel design will provide for sediment transport past infrastructure while allowing for deposition in the lowest portion of the alluvial fan near Steigerwald Lake.
- Channel Mobility – Restore the ability for the creek to meander across its alluvial fan at its connection to Steigerwald Lake.
- Maintenance – Minimize or eliminate the need for stream maintenance.

Channel design will be geomorphically appropriate and take into account the existing and new infrastructure within this reach. This infrastructure includes:

- The existing SR 14 Bridge and embankments, and the Railroad Bridge and embankments;
- Adjacent properties along Gibbons Creek; and
- The proposed west setback levee, including the flood wall and engineered berm.

The integrity of this infrastructure will be maintained during significant flood events through the implementation of infrastructure protection criteria described in **Table 4-2**.

Table 4-2 Infrastructure Protection Design Criteria: Gibbons Creek (North Reach).

Infrastructure Concern	Hydraulic Criteria*	Reference
Flooding	No increase to flood water levels up to the coincident 0.2% ACE event (combined Columbia River Gibbons Creek winter flow event) for adjacent landowners	USACE staff direction 2/2016
Bridge flow passage	Meet existing or improve flow passage	Coordination with WSDOT (2014a)
Bridge foundation scour	Gibbons Creek 100-year event flow (1% ACE)	WSDOT Hydraulics Manual (2014b)
Floodwall bank protection	Gibbons Creek 100-year event flow (1% ACE)	To be coordinated with USACE
Levee bank protection	Gibbons Creek 100-year event flow (1% ACE)	FEMA 44 CFR 65.10 (b)(3)

*Design criteria is specific to Gibbons Creek only

4.4.1 Channel Alignment

Realignment of the northern Gibbons Creek channel is focused on providing for natural function while maintaining existing and proposed infrastructure. Review of historic photos and topography maps (USGS 2015) from the 1930's to early 1960's indicate that the historic channel sinuosity north of SR 14 was generally low, with sinuosity increasing closer to the connection with Steigerwald Lake. The proposed channel alignment follows a similar pattern as shown in construction drawings C4.1 to C4.7 in **Appendix A**.

The new channel alignment north of SR 14 will restore natural planform variation to the system while increasing floodplain storage along the western bank within the vicinity of the new floodwall. At the SR 14 Bridge, the existing straight channel alignment (approximately 150 feet upstream and 200 feet downstream of the bridge) is maintained. Downstream of the SR 14 crossing, the channel meanders towards Steigerwald Lake and will be constructed as a shallow inset channel with a low floodplain to mimic historic alluvial fan conditions.

4.4.2 Channel Geometry

The Gibbons Creek channel geometry is designed to provide natural sediment transport, hydraulic, and biological processes, while reducing flood and erosion risks for adjacent properties and infrastructure. The channel design also aims to maximize complexity and function of stream and floodplain habitats. The design was developed based on sediment transport and hydraulic modeling analysis (W2r 2017). The HEC-RAS model (HEC 2016) was used to simulate long-term sediment transport trends to assess likelihood of morphological changes over a 30-year or longer period. Based on the determined long-term bed tendencies, unsteady flows at present time under both proposed and existing conditions for 50%, 20%, 10%, 4%, 2%, 1%, 0.2% ACE design flood events were then simulated. Simulation results were used to examine changes in flood and erosion risk for adjacent parcels and infrastructure.

The following channel dimensions were determined for Gibbons Creek from the sediment transport (mobile bed, quasi-unsteady flow simulation) results:

- Bed slope: 0.5 percent to 1.2 percent is in-line with the alluvial fan slope and thus will be consistent with historic channel slope.
- Channel bottom width: 18-20 feet.
- Channel side slopes: 3H:1V would be used, similar to channel characteristics upstream of SR 14.
- Channel top width: 25-30 feet; this top width coincides with the existing channel top widths upstream of the SR 14 Bridge and is in line with the WDFW bankfull channel width estimate Equation C.1 which estimates a width of approximately 30 feet. (WDFW 2013).
- Channel depth: 1.0 to 2.0 feet; low channel depths for most of the restored reach as a conservative estimate intended to increase bank overtopping and floodplain inundation.
- Width to depth ratio: greater than 10.

The proposed channel cross sections are shown in construction drawings C5.1 and C5.2 in **Appendix A**.

Excavation of the new alignment may unearth alluvial deposits that would provide for an initially stable channel bed material. However, the potential to daylight sufficient alluvial deposits lessens with the channel downstream distance, as the new alignment extends to the edges of the alluvial fan. As needed, the realigned channel will be lined with coarser bed materials from the existing channel and remnant overflow channel. Additional stability will be added adjacent to the west setback levee and Gibbons Creek North flood protection berm by constructing cobble riffles to prevent damage to these critical pieces of infrastructure.

4.4.3 Overflow Storage Area

The vacant field, to the east of Gibbons Creek and north of SR14 (owned by USFWS), provides 50 acre-feet of overflow storage during storm events. Under restored conditions, the Gibbons Creek channel geometry will allow the Creek to overtop its banks under extreme flood events, spill into this storage area, and eventually drain through two 24-inch culverts under SR14. These two culverts will be retrofitted with flap gates to prevent Columbia River backwatering from the south of SR14 into the storage area.

4.4.4 Channel and Floodplain Habitat

Channel and floodplain habitat complexity will be improved through the following design elements:

- Pool riffle morphology and buried channel-spanning logs as described in Section 4.4.6;
- Floodplain cobble bars with willow/log trenches consistent with natural high-energy creej habitats and to minimize the risk of channel adjustments, particularly at the upstream extent of the restore creek. The cobble bars and willow trenches will act as extensions of the riffles into the floodplain.
- Various types of wood habitat structures and floodplain nurse logs along the channel and floodplain as described in Section 4.6;
- Live stake planting to increase channel bank stability and provide other ecological functions;
- Riparian vegetation planting as described in Section 4.14;

4.4.5 Pedestrian Bridge

A new pedestrian bridge will be constructed on the northernmost private property adjacent to Gibbons Creek. The new bridge will replace two existing dilapidated bridges that the landowner uses to access and maintain the property east of the creek. One of these existing bridges must be removed to facilitate construction of the west setback levee. The new bridge will be located at approximately the same location as the northernmost existing bridge, which is approximately 100 feet downstream (south) of the BNSF railroad bridge and Old Evergreen Highway.

The design approach for the bridge and abutment will be performance specification, whereby design criteria are provided to the contractor, and the bridge manufacture designs the bridge and abutment system (pre-engineered product). A summary of the design criterial and characteristics of the new bridge is shown in Table 4-3.

Table 4-3 Summary of pedestrian bridge design.

Bridge criteria / characteristic	Value / description
Existing bridge length	*Approx. 52 feet*
Bridge design approach	WDFW Stream Simulation
Bankfull width of creek	25 - 30 feet (per WDFW 2013)
New bridge length	50 feet (to span existing enhanced banks)
Bridge width	6 feet
Bridge type	Pre-engineered timber

Bridge criteria / characteristic	Value / description
Railing / curbs	No hand rail; 16" timber curb
Bridge decking	Rough cut timber
Load rating / purpose	Pedestrian, small equipment (mower)
Low chord elevation	49.0 feet NAVD88
100-year creek water surface	48.5 feet NAVD88
Channel thalweg elev. below bridge	41 – 42 feet NAVD88
Bridge abutment scour protection	Roughened rock toe (cobbles) with rootwads (see Section 4.4.6)
Bridge abutment	Precast concrete; Allow. soil bearing: 2,000 PSF

4.4.6 Scour Protection / Habitat Enhancement Riffles, Logs, and Bars

Several design measures will be implemented to prevent scour and enhance habitat in Gibbons Creek. These measures include a roughened rock toe, cobble bands, cobble riffles, streambed gravel bars, and buried log structures and are summarized in Table 4-4.

The roughened rock toe will be located from the mid channel up into the Gibbons Creek North flood protection berm along its whole length to prevent bank erosion and provide channel margin diversity. This measure will also be implemented over a 15-foot-long swath under the Hickey Pedestrian Bridge to prevent bed scour underneath the bridge and provide velocity refugia for fish passage (WDFW 2002).

Cobble bands will be used to provide scour protection to the SR 14 bridge abutments while allowing natural scour in the alternating bands of native material which will promote channel form diversity and improve fish passage.

The riffles and buried log structures will be embedded in the stream such that material at grade will erode from the downstream side of the riffle/structure and the crest of each riffle/structure will backwater the toe of the next riffle/structure upstream. Three of the riffles will proceed downstream from the top of the channel construction, and five will proceed downstream from SR 14 alternating with three buried log structures at the downstream end, all at crest spacing distances of 70-80 feet.

Table 4-4 Summary of Gibbons Creek Scour Protection / Habitat Enhancement Measures.

Measure	Description	Intent
Roughened Rock Toe at SR 14 (Cobble Bands) and at Hickey Bridges	Dimensions: 2'D X 15'L layer Extents: varies per cross section width Rock size: 10" D50 (large cobbles); Wood habitat structures (WHS) embedded No. of cobble bands at SR 14: 3 Band length: 20 feet Native sediment: 20' length between bands	Prevent scour below bridges, provide velocity refugia for fish passage; cobble bands maximize scour prevention as well as gravel for improved habitat
Roughened Rock Toe at Floodwall / Berm	Dimensions: 2'D X 15'L Extents: per plan Rock size: 10" D50 (large cobbles); Wood habitat structures (WHS) embedded	Prevent bank erosion along berm and provide channel margin complexity
Cobble Riffles	Riffle dimensions: 2'D X 20'L X 30'W Material: 10" D50 cobbles Vertical stagger: 1' (drop between adjacent riffles) Long. spacing: 60' – 90'	Provide grade control in key channel reaches while allowing natural scour and formation of pools below riffles
Floodplain Cobble Bars with willow baffles	Dimensions: 2'D X 30'L X variable W Material: 6" D50 Cobbles (smaller than riffles) Willow length: 6' X 1" livestakes, Length / no. of baffle: (4) at 30' L each (per bar) 1' DBH Nurse Logs at bottom of willow trench Baffle orientation: staggered in coble bars (see plans)	Prevent avulsion around riffles in floodplain at upstream extent of channel (highest energy) using natural-simulated features
Streambed Gravel Bars	Dimensions: 1'DX40'LX7'W Material: site sourced sediment (2.5" minus round gravel) Placement: 80'-120' spacing, along channel margin	Replicate existing bed material conditions in the new channel and limit temporary, post-construction erosion
Buried Log Structures	No. of Structures: 3 Materials: (1) 40' long 30" DBH buried log (1) 30' long 12" DBH rootwad log (2) 16' long 10" DBH pier logs 10" D50 Cobbles along margins Placement: in sequence with cobble riffles	Provide grade control in key channel reaches while allowing natural scour and formation of pools below logs

Scour protection cobble was sized to remain stable under 1% annual exceedance event using the following well-established rock stability assessment methods; WSDOT (2010), USACE/Maynord (1994), Pilarczyk (1995), ASCE and HEC-11. Assumptions for the use of these methods include:

- 1% annual exceedance flow: 1,130 CFS per HEC-HMS (WEST 2017)
- Representative peak depth-averaged velocity: 8 ft/s (HEC-RAS)
- Representative peak flow depth: 5 ft (HEC-RAS)

- Channel side slopes: 3H:1V
- Specific weight of stone: 165 lb/ft^3
- Upscaling factor for round rock: 1.2

Gradation for the cobble riffles will be as described in Table 4-5. The cobble gradation includes 24" boulders to vary hydraulic behavior across the riffles for improved morphological diversity and fish passage. All boulders will be embedded at least 2/3 of its diameter. Native sand and organic sediment will be washed into the riffle rock after placement of the cobbles.

Table 4-5 Cobble Riffle Gradation

Rock Size (Inches)	% Passing by Weight
24	100
12	90
10	50
8	25
4	10
1	0

Gradation for the floodplain cobble will be as described in Table 4-6. This cobble will be buried at grade and have fine sediment washed into it as described in the specs.

Table 4-6 Floodplain Cobble Gradation

Rock Size (Inches)	% Passing by Weight
12	100
6	50
4	25
2	10
1	5

Native streambed substrate will be excavated from the existing creek as part of the floodwall construction. This native material will be placed in gravel bars to be naturally distributed and sorted through the reach such to more quickly reestablish the new channel and limit scour and subsequent deposition downstream. Limiting short term channel adjustments are prudent because:

- the channel design relies in part on floodplain vegetation establishment for avulsion prevention,
- the new channel will be constructed in relatively fine sands and gravels comprising the current floodplain of the creek,
- erosion risks in the creek near the floodwall and levee are critical, and
- seeding the channel with native gravels will limit adjustments to the channel and floodplain.

Based on assessment of the existing sediment characteristics in Gibbon's creek (presented in the Gibbons Creek Hydraulics & Sediment Transport Report) the native sediment (mix of surface and subsurface gravels) will have a D50 of approximately 1 to 2 inches, with a maximum size of approximately 5 inches. This size range will be targeted for construction of the gravel bars in the new channel.

4.5 Infrastructure Considerations

This section summarizes the effects of the proposed restoration on infrastructure within or adjacent to the project.

4.5.1 West Setback Levee and Floodwall/Berm

The risk of scour or impinging flows against the toe of the new setback levee during peak storm events, such as the 1% ACE and 0.2% ACE events, is not expected to be high. Levee overbuild sections will be constructed on the waterward slope of the levees to act as wave erosion protection. Levee overbuilds will also be constructed along the floodplain of Gibbons Creek downstream of SR 14 to minimize creek impacts on the new levee. The overbuild sections will be wide, have a low slope, and vegetated as opposed to protected with riprap for consistency with improved habitat. The overbuild sections are sacrificial and are not relied upon for levee slope stability or seepage control. The levee overbuild sections are described in Section 4.9.

Erosion protection measures for the floodwall/berm (part of the west levee segment) will consist of roughened rock toe streambank protection incorporated into the channel banks adjacent to the floodwall at all locations (see Section 4.4).

4.5.2 WSDOT Right of Way (SR 14 Bridge and Roadway)

The SR 15 bridge was designed to convey the 50-year flow in Gibbons Creek according to WSDOT as-constructed drawings. Currently, the bridge's conveyance area is reduced by over 50% compared to its design, and the U.S. Fish and Wildlife Service (USFWS) must dredge (often multiple times per winter) to maintain channel capacity (ESA 2016a – See Appendix D-2). Even with active channel maintenance, water levels in the creek commonly approach or reach the bridge low chord (including in January 2009 and December 2015 when the creek crested at and five inches below the low chord, respectively).

Gibbons Creek flood risk is of concern to nearby properties given the uncertainty of USFWS continuing to receive regulatory approvals required to dredge and the likelihood that Gibbons Creek flood levels will increase in the future (due to both increasing intensity of rainfall runoff events and development in the watershed). If dredging were to cease, the channel would likely fill with sediment and significantly increase the risk of inundation of adjacent properties upstream and the risk of roadway embankment and bridge abutment scour.

As summarized in Section 3.5, hydraulic analysis of the creek shows that under existing conditions and the extreme 0.2% ACE ("500-year") event, the creek does not overtop the bridge / road. Instead, the creek over-flows west along the right-of-way and onto the adjacent private property. Moreover, sediment and debris accumulation in the creek due to the existing diversion structure occurs at a far greater frequency than the 0.2 ACE event, and sediment and debris accumulation could exacerbate adjacent property flooding, road overtopping, and bridge/road scour risks.

In contrast, hydraulic analysis shows that under proposed conditions the creek would not overtop the SR 14 bridge / roadway even under the extreme 0.2% ACE ("500-year") event, and that the creek does not overflow onto the adjacent private property due to the new floodwall along its west bank.

To mitigate scour risks to the SR 14 bridge and roadway, scour countermeasures are incorporated into the restoration design. These measures, roughened rock toe bank protection and cobble riffles to limit lateral and vertical channel adjustments are described in Section 4 and shown in the Gibbons Creek restoration plan sheets in Appendix A.

4.5.3 BNSF Right of Way

The railway was built prior to the levee system and was sited to minimize potential flood impacts. In the immediate project vicinity, the railroad line was constructed along the base of a natural hillslope rather than on a constructed embankment. As a result, the elevation of the railway line and adjacent access road in this area is several feet (approximately 6-7 feet) above the existing levee crest elevation.

The lowest portion of the BNSF railway (access road and rail line) is approximately at elevation range 52 to 55 feet NAVD88, well above the (0.2% ACE) water surface elevation of approximately 38 to 39 feet NAVD88. The slope of the hillside below the railway line appears to be 2H-4H:1V or flatter and heavily vegetated. The horizontal distances from the railway to commonly inundated areas of the Refuge appear to be on the order of 80 feet. If this hillside remains heavily vegetated, the overall risk to the railway infrastructure would likely remain low.

Based on the topography, the toe of the railroad embankment (elevation range 30-35 feet NAVD88) will become inundated around a 2% ACE event (elevation 33-34 feet NAVD88). Since the 1% ACE event is approximately 35 feet NAVD88 and does not rise significantly above the toe of the embankment, the flood is not expected to have an effect on stability. Also, drawdown stability is not expected to have a significant effect because Columbia River floods generally recede slowly.

Wind-wave impacts were also evaluated adjacent to the railroad embankment (ESA 2016b). Findings from the wind-wave assessment were that the critical (most frequent/highest waves) zone of erosion potential along the embankment was at elevation 15-20 feet NAVD88, which is well below the embankment toe.

Levee Overbuild to Accommodate BNSF Maintenance
Coordination with BNSF resulted in a determination that there will not likely be any adverse effects on existing railroad structures in the area of the project. To accommodate future railroad maintenance activities, an earthen overbuild will be constructed, as described in Section 4.9. The overbuild will include approximately 8 to 9 feet of fill (embankment) on top of the east setback levee, consistent with ground elevations of the existing track adjacent to the overbuild.

4.6 Wood Habitat Structures

Wood habitat structures (WHS) would be placed throughout the restored channels and floodplains to increase cover habitat and channel /hydraulic diversity, and provide substrate and organic food source to support the macro-detrital food web. A significant amount of wood is expected to be placed in areas where it would naturally occur in a manner that closely mimics natural accumulations for that particular habitat type. The reference density assumed in developing the log structure design and quantity is approximately 19 pieces per 100 LF of channel/floodplain.

A summary of structure locations, quantities, and log piece counts is shown in Table 4-7.

Table 4-7 Wood Habitat Structure Log Summary.

Location	Description	WHS Type	# of Structures	Log type per Structure						
				Buried - L: 40 ft DBH: 30-48 in	Keyed - L: 16 ft DBH: 16-36 in	Footer - L:16 ft DBH: 16-36 in	Rootwad Pin - L: 30 ft DBH: 12 in	Chan. Span. Log - L: 40 ft DBH: 16-24 in	Small Pier - L: 12 - 18 ft DBH: 6-16 in	Large Pier - L: 12-18 ft DBH: 16-24 in
Gibbons (Up-stream SR14)	Single Keyed Log	1	2		1					
	Multiple Keyed Logs	2			1	1				
	Multiple Keyed Logs, pinned	3	8		1	1			1	
	Simple Channel Spanning Jam	5	2		1			1	1	2
	Complex Channel Spanning Jam	6			3			1	1	3
	Subtotal		**12**	**0**	**12**	**8**	**0**	**2**	**10**	**4**
Gibbons (Down-stream SR14)	Single Keyed Log	1	12		1					
	Multiple Keyed Logs	2	9		1	1				
	Multiple Keyed Logs, pinned	3	14		1	1			1	
	Simple Channel Spanning Jam	5	1		1			1	1	2
	Complex Channel Spanning Jam	6	3		3			1	1	3
	Buried Log	7	3	1			1		2	
	Subtotal		**39**	**3**	**45**	**23**	**3**	**4**	**24**	**11**
Channel 1	Single Keyed Log	1	4		1					
	Multiple Keyed Logs	2	7		1	1				
	Multiple Keyed Logs, pinned	3			1	1			1	
	Simple Channel Spanning Jam	5			1			1	1	2
	Complex Channel Spanning Jam	6			3			1	1	3
	Subtotal		**11**	**0**	**11**	**7**	**0**	**0**	**0**	**0**
Channel 2	Single Keyed Log	1	4		1					
	Multiple Keyed Logs	2	2		1	1				
	Multiple Keyed Logs, pinned	3	19		1	1			1	
	Simple Channel Spanning Jam	5			1			1	1	2
	Complex Channel Spanning Jam	6	1		3			1	1	3
	Subtotal		**26**	**0**	**28**	**21**	**0**	**1**	**20**	**3**
Channel 3	Single Keyed Log	1	13		1					
	Multiple Keyed Logs	2	34		1	1				
	Multiple Keyed Logs, pinned	3	22		1	1			1	
	Simple Channel Spanning Jam	5	7		1			1	1	2
	Complex Channel Spanning Jam	6	6		3			1	1	3
	Subtotal		**82**	**0**	**94**	**56**	**0**	**13**	**35**	**32**
Channel 4	Single Keyed Log	1	7		1					
	Multiple Keyed Logs	2	6		1	1				
	Multiple Keyed Logs, pinned	3	5		1	1			1	
	Simple Channel Spanning Jam	5			1			1	1	2
	Complex Channel Spanning Jam	6	1		3			1	1	3
	Subtotal		**19**	**0**	**21**	**11**	**0**	**1**	**6**	**3**
Total Channel Pieces			**189**	**3**	**211**	**126**	**3**	**21**	**95**	**53**
Total Channel Piece Count (Coniferous)										**512**
Expanded Habitat Piece Count (Deciduous/Coniferous Mix)										**1240**
GRAND TOTAL										**1752**

WHSs will be constructed with the top log keyed into the native subgrade to resist buoyancy and scour forces and secure the footer log in place. Pier logs will also be used to naturally anchor logs in place where scour risk is expected, particularly upstream of SR 14.

Habitat logs will also be placed throughout the expanded habitat areas for general enhancement of micro-habitat features. These logs will either have rootwad attached or have limbs partially intact for additional habitat and organic input. It is anticipated that during construction of the project, all trees removed during clearing will be salvaged and incorporated into WHSs.

These logs will be placed in the expanded habitat areas, embedded into the ground. The cost for these logs will be included in the clearing and grubbing, and we estimate 30 to 40 logs (larger than 8 inches DBH) will be cleared to accommodate new channels and levees.

4.7 Reconnected and Expanded Habitat

Restoring hydrologic connectivity between the Columbia River and its historic floodplain will reconnect existing low-lying regions of the Refuge land (below 23.7 feet NAVD88 in elevation) to seasonal shallow inundation during the spring freshet. This existing, reconnected habitat area will be enlarged through excavation and grading. The purpose is to expand areas that are below elevation 23.7 feet NAVD88 (the habitat elevation criterion for this project) in key areas throughout the site to create additional habitat. This reconnected and expended habitat will provide hydraulic velocity refuge, cover and an important food source for rearing juvenile salmonids. Reconnected and expanded habitat areas are shown in **Figure 1-2** (light green and green/blue hatched areas, respectively). **Table 4-8** is a summary of existing and expanded habitat areas is shown.

Table 4-8 Summary of Existing and Expanded Habitat Areas

Description	Area (Acres)	Notes
Reconnected Habitat Area	455	Existing areas below EL 23.7 feet NAVD88.
Expanded Habitat Area	115	New area below EL 23.7 feet NAVD88. Includes channel excavation.
Total	**570**	

To maximize expanded habitats and habitat connectivity, the proposed grading areas are located immediately adjacent to existing low areas. Much of the existing low land is dominated by reed canary grass cover and will benefit from the surface vegetation scalping. After excavation, expanded habitat areas will be densely seeded with a native wetland seed mix. In areas near proposed channels, revegetation may also include willow scrub plantings. Revegetation is discussed in more detail in Section 4.14.

4.8 Public Access

4.8.1 Existing Public Access Facilities and Project Impacts

Steigerwald NWR provides public access to the Refuge from a parking lot south of SR 14 and east of Gibbons Creek. The lot provides parking for 20 cars (2 ADA) and 1 bus/RV. Facilities include a waterless restroom with two vault toilets, bike racks, kiosk and trailhead. The trailhead provides access to a pedestrian-only trail with a number of interpretive art elements that connects to the seasonally-closed Redtail Lake loop trail and a multi-use trail (pedestrians, dogs on-leash, bikes, and horseback riders) on the Columbia River levee -- the Columbia River Dike Trail (CRDT). Non-public vehicle access to the refuge and Columbia River levee is also provided from this lot via a gated road along the Gibbons Creek elevated channel.

4.8.2 Public Access Design Intent and Criteria

The intent of the public access design is to provide similar site access but an improved visitor experience following restoration actions. The following design criteria were established collaboratively with input from USFWS, the Estuary Partnership, the Port, FOCG, and other stakeholders. The existing parking lot and access trail will be moved to the west side of the west levee where it will be protected from seasonal flooding from the restored Gibbons Creek delta and Columbia River. The number of available parking spaces would be increased from 20 (2 ADA) to 30 (2 ADA), maintaining parking for one bus or RV, and salvaging and relocating many of the interpretive art components. However, some of the interpretive art components will not be as relevant to the new visitor experience (i.e. water control art piece), and will therefore not be relocated on the site.

Table 4-9 Linear Access Element Design Criteria

Linear Access Feature	Width (FT)	Surface	User	Max Slope	Min Radii (FT)	Trail El.* (FT NAVD88)
Entrance Road	24	Gravel	Car, RV, Emergency Services, Tractor	NA	NA	NA
Maintenance Access Road	12	Gravel	Car, Emergency Services, Tractor (may be used as interior trail)	5%	40	Varies
Multi-Use Columbia River Dike Trail (CRDT)	10	Gravel	Pedestrians, Horses, Bicycles, Dogs on-leash, Polaris-style maintenance vehicles	5%	36	33 - 38
CRDT Channel Crossing	10	Gravel	Pedestrians, Horses, Bicycles, Dogs on-leash, Polaris-style maintenance vehicle	5%	NA	23.0 Min.

Linear Access Feature	Width (FT)	Surface	User	Max Slope	Min Radii (FT)	Trail El.* (FT NAVD88)
CRDT Bridges	12	Timber or other Non-Slip Decking	Pedestrians, Horses, Bicycles, Dogs on-leash, Polaris-style maintenance vehicle	NA	NA	27 to 30
Interior Trails	6	Gravel	Pedestrians only	5%	--	Varies

**Span and channel crossing elevations minimize periodic inundation. Based on a 10-year record, the Columbia River crossing elevations of 23 feet NAVD88 would be inundated an average of 12 days per year.*

Emergency Response Access

Any emergency on the Refuge would be a 911 call routed to Washougal Emergency Management System (EMS) for initial response. The channel crossings on the CRDT provide year-round vehicle response for emergencies except the 12 days per year, on average, when the crossings are submerged, leaving a small annual window when vehicle access would be precluded. In these limited circumstances, pedestrian response would be deployed, which is consistent with other trails in the CRGNSA that do not have motorized vehicle access.

4.8.3 Proposed Public Access

The restoration project would remove 2.2 miles of the Columbia River levee, the Gibbons Creek elevated channel, and an interior access road embankment. These actions would result in the removal of a portion of the CRDT and access road network.

The proposed public access is shown on **Figure 4-1**. The parking lot and associated facilities (restroom, bike parking, and trailhead) will be relocated to the west (interior) side of the west setback levee. Relocation is prudent to prevent impacts from relatively rare Columbia River floods and it also provides more room for Gibbons Creek alluvial fan restoration. The parking lot will be moved west of the proposed west setback levee. The automatic gate will be connected to the existing buried power and telecom just outside of the ROW. Water for establishment irrigation in the lot will be provided by water truck. This will eliminate the need for either a new well or a new connection to city water located some distance north across SR 14. Suspending a well waterline from the SR 14 Bridge over Gibbons Creek to provide water from the existing well was deemed undesirable.

The trailhead provides access to a public pedestrian-only trail located atop the new setback levee that also functions as a maintenance vehicle access road. Interpretive art elements will be relocated to this trail where appropriate and compatible with levee operations and maintenance. The new overlook will be positioned on the west setback levee overbuild where the maintenance vehicle access road meets the levee road, providing visitors with their first expansive views of the refuge. The trail connects to the CRDT where the west setback levee meets the existing Columbia River levee. The CRDT will be reconstructed at a lower elevation where the existing Columbia River levee is removed (i.e., between the two setback levees) and will meander across the broad natural fluvial levee. This trail will include an at grade crossing of Channel 1 and two bridges (Table 4-10) to allow users to cross Gibbons Creek (Channel 3) and Channel 2. The seasonally-closed Redtail Lake loop trail will not be impacted during construction, although some interpretive elements from this loop will be relocated to new facilities on the site. Access to this trail will continue to be provided from the CRDT. Bridge design will be refined in the next phase of the project.

Table 4-10 Preliminary Proposed Bridges Characteristics

Bridge / Location	Type	Nominal Length (FT)	Low Chord El. (FT NAVD88)	Deck El. (FT NAVD88)	Load Rating
Bridge 1 over Channel 2	Pre-engineered clear span	100	TBD	30	Light duty vehicles
Bridge 2 over Gibbons Creek	Pre-engineered clear span	150	TBD	27	Light duty vehicles

A second Columbia River overlook, similar to the existing one near the existing fish ladder is proposed along the new CRDT between the Channel 2 and the Channel 3 crossings. This overlook will consist of simple fencing and rock benches and will provide the visitor with views of the Columbia River and the restored channel outlets.

Other site improvements include new fencing, new signage, updated signage, and relocated rock benches and bike racks.

4.9 Levees

A primary feature of the proposed project is to reconnect floodplain and wetland habitats to the Columbia River by removing a 2.2-mile portion of the existing Columbia River levee and constructing two new setback levees. The setback levees will provide an equivalent-level of flood protection outside of the restoration area. In order to determine the appropriate crest elevations for the new setback levees, we reviewed the 1969 Columbia River levee as-built drawings (CLW-123-11/5). The existing levee is referred to as the Camas-Washougal Levee in these documents. The drawings were used to identify the existing levee design elevations at the locations where the proposed setback levees would tie into the existing levee.

Based on the tie-in points of the setback levees, we have developed the following table and proposed levee elevations. The vertical datum of the as-built drawings is MSL 1947 -- equivalent to the 1947 adjustment of NGVD29. To convert these elevations to NAVD88, 3.40 feet were added to all elevations (as documented in the May 26, 2009 memorandum “Phase 1 Documentation Review Port of Camas-Washougal Levee District” to David Ripp).

Table 4-11 Existing and proposed levee crest elevations.

Location	Station	Crest elevation (FT MSL)	Crest elevation (FT NAVD88)
Downstream (west) end of existing levee	L 0+00	41.6	45.0
West setback levee	L' 57+00	42.3	45.7
East setback levee	L' 172+00	42.9	46.3
Upstream (east) end of existing levee	L' 205+38	43.0	46.4

Note: existing levee crest elevations are based on 1969 as-built drawings -CLW-123-11/5)

Design of two setback levees was performed following the principles presented in USACE manual, Design and Construction of Levees (EM 1110-2-1913) and other USACE resources. USACE's guidelines recommend that levee designs consider and analyze: (i) underseepage and through seepage; (ii) slope stability; and (iii) settlement (i.e. loss of freeboard) of representative sections of the levee. These analyses were performed on eight (8) levee sections that represent the various foundation conditions and embankment height combinations along the two levee alignments.

A field exploration and laboratory testing program was performed to develop foundation subsurface conditions and soil parameters to use in the design of the setback levees. The field explorations consisted of a site reconnaissance, drilling 41 boreholes along the levee centerlines, landside and waterside of each setback levee, and performing in-situ testing. Soil samples were collected from in-situ density tests and thin-walled tubes to collect undisturbed samples for laboratory testing. Representative permeability of the foundation soils was determined by performing falling head field permeability tests at select locations and depths throughout the site. The drilling program included installation of six (6) standpipes with vibrating wire piezometers (VWPs) to monitor the seasonal groundwater fluctuation.

Soil samples were transported to Cornforth Consultants' laboratory where various soil properties were tested. Laboratory testing consisted of grain size distribution (mechanical sieve and hydrometers), natural water contents determination, consolidated-undrained triaxial tests, one-dimension consolidation tests, and Atterberg Limits determination. These laboratory tests were used to determine the foundation soils characteristics, permeability, plasticity, shear strength, and compressibility.

Results of the field investigations and laboratory testing were used to develop a geologic/analysis model sections of the site along both levee alignments. The geologic models show that the southern half of the Refuge has relatively thick deposits of compressible soil. The northern half of the site typically has thinner deposits of compressible soils as denser soil layers tend to get shallower to the north. The groundwater is relatively shallow and ranges from 4.5 to 21 feet below the ground surface.

The soil parameters and geologic model was used to develop cross-sections to analyze the stability, seepage and potential settlement of each segment (referred to as a "Reach" in the report) of the setback levees using the design flood level. Seepage and slope stability analyses were performed on each section using SEEP/W and SLOPE/W (part of a bundle of geo-engineering software programs created by GeoStudio, Inc) to determine the stability of the levee under design flood conditions. A limit equilibrium method was used to calculate the inboard and outboard factors of safety for the landsides and watersides of the levees, respectively. The settlement due to embankment loading was approximated using soil consolidation parameters, a (modified) Boussinesq pressure distribution, and a spreadsheet program for each segment of the levee. The maximum settlement occurs at the centerline and approaches zero settlement near the toes of the levee.

In general, setback levees constructed using 12-feet wide crests with 4H:1V (horizontal:vertical) and 3H:1V side slopes satisfy the conditions of stability and seepage outlined by the USACE. A summary of the analyses results on select design levee sections are summarized in the table below:

Table 4-12 Analyses Results on the Design Levee Sections at Design Flood Conditions

Reach	Station	Steady-State Seepage Exit Gradient	Slope Stability Factor of Safety		Settlement (FT)
			Inboard	Outboard	
E-1	E 2+41	0.29	2.0	2.4	1.0
E-2	E 12+41	0.44	1.6	2.6	2.5
E-3	E 17+41	0.37	1.6	2.6	2.0
E-4	E 20+99	0.39	1.7	2.6	1.0
W-1	W 8+36	0.31	1.9	2.5	3.5
W-2	W 26+37	0.34	1.8	2.7	3.0
W-3	W 33+36	0.37	1.6	2.7	2.7
W-4	W 43+37	0.31	1.9	2.6	0.6

Analyses of the embankment and foundation for slope stability and the potential seepage through both areas indicate that the critical factors of safety for slope stability at all locations exceed the minimum requirements established by the USACE in their engineering guidelines (FS > 1.4). The seepage results show exit gradients at the interior toe of the embankment slope that are below are less than or equal to the maximum value of 0.5, as recommended by USACE guideline.

The settlement of the levees varies for along reaches depending on foundation conditions and levee height. The calculated settlement values in some areas would result in inadequate freeboard (i.e. less than 3 feet) if constructed to design height. Therefore, a design/construction strategy, such as overbuilding the levee, foundation improvement and/or staged construction, will need to be adopted to mitigate loss of freeboard.

4.9.1 Levee Overbuild Sections for Wave Protection

Overbuild sections of the west and east setback levees are intended to serve as protection from combined high water and wind (wind/wave) events that could erode the exterior (waterward) slopes of the levees. These overbuild areas are not required to meet levee seepage and stability requirements. The overbuild sections will be vegetated with riparian vegetation (Appendix A: L3 Sheets & Sheet L4.0) and are intended to replace riprap levee protection for consistency with the habitat objectives of the project.

The primary intent of the vegetated overbuilds are to resist wind-wave based erosion (during high Columbia River stages). Gibbons Creek flows are not expected to affect the toes of the overbuilds, as the creek is sufficiently far from the levee toes, and the west floodplain of the creek downstream of SR 14 slopes upward and meets the overbuild toe at an elevation above the 0.2 ACE event stage in the creek (see Appendix D-3).

Wind-wave analysis supporting the levee overbuild section design is included in Appendix D-4. A summary of conceptual design features of the levee overbuild sections is listed in Table 4-13.

Table 4-13 Summary of Levee Overbuild Design for Wave Erosion Protection.

Wave-break berm (overbuild) feature	Value	Notes
Design wave height	10-year wind: 2.6 feet 100-year wind: 3.8 feet	West & east levees (Appendix D-4)
Critical erosion elevation range	17 -22 feet NAVD88	West & east levees, SR 14 (Appendix D-4)
Overall berm elevation range	Toes: 15 – 30 feet NAVD88 Top: 35 feet NAVD88	
Sideslopes	Critical erosion zone: 20H:1V Low erosion zone: 4H-6H:1V	Conceptual overbuild design reflects simple 8H:1V single slope
Slope lengths	Critical erosion zone: TBD	Horizontal distance along berm to attenuate waves
Vegetation	Dense, native grasses, shrubs, willows	Species to be determined (NRCS 2014)
Maintenance	Minimal to none	Consistent with other habitat planting areas
Inspection access	Walkable grass access paths	Walkable path design - TBD

4.10 East Levee Interior Drainage Structure

The new levee on the east boundary of the project area will alter existing drainage from the privately-owned ranch (see **Figure 1-2**). An analysis of interior drainage is required to support the design of a drainage structure through the new levee. This analysis is provided in Appendix D-3.

Existing drainage features on the ranch include an intake that diverts water from Lawton Creek to a storage pond. The storage pond has flashboards (overflow weir) that drain west through a drainage channel. The drainage channel is located at the low point of the property and thus also collects stormwater runoff from the surrounding grass fields. The portion of the site south of the basin ridge line drains to the existing depressional pond and the existing drainage patterns in this portion of the site will not be altered by the proposed levee. **Figure 4-2** summarizes the site drainage conditions and features.

4.10.1 Drainage Survey and Ground Cover

For initial drainage design and to supplement the photogrammetry-based ground topography, a local topographic survey was conducted of the existing drainage channel in the vicinity of the proposed eastern levee. The supplemental survey characterized the average channel slope through the reach, average channel dimensions (bottom width, top width, side slopes), and existing culvert invert elevations. The survey was based on an iron rod benchmark that will be tied into the larger site survey during the next phase of design.

The private ranch is an actively grazed pasture with few trees or shrubs. There are several buildings and access roads in the northeast corner of the site. There is also a large stock pond located in the middle of the site. The site soils are categorized as both hydrologic groups B and C/D (approximately 50% of each soil group).

4.10.2 Design Criteria and Characteristics

The interior drainage structure was designed according to the following USACE Engineering Manuals:

- EM 1110-2-1913 Design and Construction of Levees, dated April 30, 2000
- EM 1110-2-2909 Conduits, Culverts, and Pipes, dated March 31, 1998.

The following list describes key design criteria and elements for the interior drainage structure. See Sheet D7.1 of the 30% Design Plans for details of the structure.

- 48-inch diameter culvert – The eastern levee will be classified as major and the minimum culvert pipe diameter is 48 inches. The capacity of a pipe with this diameter (> 100 cfs) by far exceeds the capacity needed to discharge the peak runoff rates (shown above) under free-flowing conditions.
- Culvert invert: 21 feet NAVD88. **Figure 4-3** shows that Columbia River stages can exceed 21 feet NAVD88 (and cause a backwater condition) for continuous periods of up to approximately 3 months.

- Seepage and piping protection – 18 inches of drainage fill around the landside third of the culvert is required to manage seepage and piping. This approach is preferred over seepage rings, which can compromise compaction and lead to failure.
- Precast concrete headwalls, wing walls, and apron – These elements will hold back the levee fill material, further discourage piping, and provide scour protection at both the inlet and outlet of the pipe.
- 50-year design life – The structure will have a design life of 50 years or longer.
- Water tight joints – The pipe material must be able to provide a water tight joint.
- Pressurized pipes – Pressurized pipes cannot penetrate the levee; thus, pump station mains must go over the levee.
- Pipe Camber – The pipe will be designed with camber to account for the expected settlement of 3.5 feet at the center of the levee. **Figure 4-3** shows the anticipated settlement curve for the levee. The design team is exploring the option of installing a test berm in the location of the proposed interior drainage structure to pre-consolidate the soil to minimize settlement of the final levee and the need for camber.
- Automatic and emergency gates – Automatic flap tide gates can malfunction due to debris preventing the gate from closing. A supplemental emergency manual sluice gate will be provided in the event the flap gate malfunctions.
- Debris fencing – The fencing will be a welded wire mesh on metal posts and will prevent trash from entering the pipe and deter beaver activity at the pipe inlet.
- Pump station – A pump station will be provided to discharge runoff during prolonged periods of Columbia River backwater. The anticipated flood elevations are described below. The pump station includes the following:
    - precast concrete wet well at pump, sized as needed
    - Ductile iron force main piping installed on top of the proposed levee.
    - Valve vault and all requisite pipe fittings, elbows, and thrust blocks.
    - (2) or more submersible, non-clog pumps (note, 1 pump is redundant)
        - System shall be able to discharge 900 to 3600 GPM as needed against 25 ft of static head and whatever friction losses are incurred in the system.
        - Power requirements shall match power available at nearby utility pole if possible.
        - Automatic float on/off control (on at EL 23, off at EL 22.5)
        - Manual control

4.10.3 Proposed Interior Flood Elevations

Inundation extents and depths for the east levee interior drainage are described in the Interior Drainage Analysis in Appendix D-3. The inundation levels for key exceedance events:

- West levee (treatment plant storage area in hydraulic model (Appendix D-3))
    - 1% ACE event inundation: 16.06 feet NAVD88
    - 0.2% ACE event inundation: 16.69 feet NAVD88

- East levee (Straub Lake storage area in hydraulic model (Appendix D-3))
  - 1% ACE event inundation: 25.5 feet NAVD88
  - 0.2% ACE event inundation: 26.3 feet NAVD88

As the project design is developed further, the design team will coordinate with project stakeholders to review expectations for the proposed flood elevation to refine interior drainage characteristics including acceptable inundation extents and pump system requirements.

4.11 Gibbons Creek Floodwall/Berm (Part of West Levee)

The Gibbons Creek floodwall/berm will align with the western levee and extend from SR 14 to the northern end of the project site along the west side of Gibbons Creek. The floodwall/berm will consist of approximately 600 feet of a permanent, cast-in-place reinforced concrete structure and approximately 180 feet of an earthen berm. The floodwall/berm will extend the project's flood protection from the north side of SR 14 to the point where the existing natural ground has risen sufficiently to protect against flooding related to changes from this project. The floodwall/berm combination structure was incorporated into the design to address the preferences of the property owners. The top of floodwall/berm will be the greater of the authorized flood elevation or 2 to 3 feet above Gibbons Creek design flood elevation. The bottom of the floodwall is preliminarily designed to be 3 feet below the invert of Gibbons Creek in order to provide the necessary "cutoff" and seepage barrier against flood events. Final top and bottom of floodwall/berm elevations will be established after 30% design. Refer to **Appendix A** for the construction drawings and **Appendix F** for the 30% Structural Analysis Report.

A summary of floodwall and earthen berm characteristics is shown in Table 4-14.

Table 4-14 Summary of West Leve Floodwall and Berm Features.

Wall / Berm Feature	Value	Notes
Floodwall length	Xxx feet	
Floodwall crest elevation (& height)	45.3 feet NAVD88 (8 feet near SR 14; 2 to 3 feet at US end)	Consistent crest elevation with rest of west levee
Floodwall material	Reinforced concrete,	'Cape horn' style formliner with pigmented sealer
Location of transition to earthen berm	Station 65+70 (see sht C4.7)	Earthen berm facilitates landowner preferences
Earthen berm crest elevation	45.3 to 46.0 feet NAVD88	El. 46 required to meet minimum freeboard at upstream extent
Berm vegetation	Dense, native grasses	Consistent with other habitat planting areas
Inspection access	10' gravel path, east side of wall	

4.12 SR 14 Closure Structure

The emergency closure structure will connect the western levee, at the levee abutment wall, to the floodwall across SR 14. The closure structure is approximately 73 ft. long and 7.5 ft. to 8.5 ft. high above the roadway. The foundation has preliminarily been designed to be 5 ft. below the roadway to effectively limit groundwater seepage from the flood event below the wall. Steel sockets, or sleeves, are cast into the foundation which will receive the temporary steel posts to be erected across and above SR14 in the case of flood. Pre-cast concrete panels will slide down between the posts and serve as the flood barrier. The pre-cast concrete panels will be stored nearby on Refuge property in a fenced, gravel area located immediately off of SR 14. The above grade elements of the closure will be installed only during emergency flood events, otherwise allowing SR 14 traffic to pass unimpeded across the eventual flood protection line. Crews from the Port will be responsible for erecting the temporary and emergency portions of the structure in advance of the flood event. Temporary pieces have been sized for a maximum weight of 5,000 pounds, which the Port determined was the maximum pick weight for their equipment. A 25-foot long WSDOT Standard concrete approach slab will be installed on each side of the closure structure along SR 14. The approach slabs are meant to minimize effects from foundation or roadway settlement and help to reduce flood seepage rates around the wall.

The western setback levee abutment consists of a permanent, cast-in-place, T-type reinforced concrete retaining wall with safety fencing on top of the wall. The top of the abutment wall will parallel the top of levee ground it retains. The bottom of the wall has been designed for global stability per preliminary geotechnical recommendations provided by the team's Geotechnical consultant. However, preliminary recommendations from the geotechnical consultant are also that no additional wall embedment is required to cutoff seepage flows so further review may be warranted.

Installation of the closure structure under emergency conditions will commence either when notified by emergency management of flooding conditions or when Columbia River water levels at the Port are within 2 to 3 feet within the bridge deck elevation (approx. 38 feet NAVD88). The closure structure will undergo trial installation runs once every two years.

Refer to **Appendix A** for the construction drawings and **Appendix F** for the 30% Structural Analysis Report.

4.13 SR 14 Roadway Raising and Improvements

The SR 14 roadway will be raised to a minimum elevation of approximately 38 feet NAVD88 at the centerline. This elevation is approximately equivalent to the 0.2% ACE stage in the Columbia River. The roadway will be raised over a distance of approximately 1,200 linear feet.

There are two existing 24-inch culverts that run beneath the road prism under the stretch of SR 14 that will be raised. These culverts will not need to be replaced as the road prism will not be adjusted by the road raise design; however, the culverts will require retrofit with backflow prevention valves (neoprene duckbill valves, or similar WSDOT-approved valves). Bedload from Gibbons Creek is not expected to affect the culverts because the topography and flow pathway along the alluvial fan of the creek is flat and long. The likelihood of these culverts filling with sediment is expected to be low within the design life of the project.

Relocation of the visitor access parking lot and construction of the SR 14 emergency closure structure will require restriping of travel lanes on SR 14 including new westbound left turn striping at 45th Street. At the emergency closure structure, the main roadwork elements include removal of asphalt and base rock, widening of the gravel shoulders to accommodate the closure structure, installation of Corten guardrail, paving, and striping. Other miscellaneous items include installation of access gates to the Gibbons Creek side of the floodwall and levee, centerline rumble strip, and pavement markers. These roadway design elements are illustrated in the 30% Construction Drawings **in Appendix A**.

4.14 Revegetation

The intent of wetland and riparian revegetation on the Refuge is to restore historic vegetation communities to the extent possible, while also considering long-term vegetation maintenance resources and existing Refuge management plans and commitments. Key historic vegetation communities include open water and wetland, dry and wet prairie, and riparian and wetland forest.

4.14.1 Vegetation Community Composition

The GLO mapping provides limited information on the plant species composition of the wetland and wet prairie communities. Dry prairies are described as having scattering trees, inclusions of woodland or savannah, and abundant grass. The riparian and wetland forest is described as an ash-mixed deciduous riparian forest with combinations of red alder, bigleaf maple, black cottonwood, white oak, and dogwood with conifers present in small quantities. This community established in response to hundreds of years of pre-dam and pre-leveed Columbia River flood processes that included a combination of highly-erosive episodic flood events as well as seasonal backwater flooding.

Though this project removes the Columbia River levee to reconnect the historic floodplain to periodic inundation, dam control will still moderate flood processes removing the highest and lowest flows. As a result, we anticipate that shallow backwater flooding will be the dominant flood process post-project. For this reason, we feel it is important to expand on historic conditions and include a number of native plant communities suited to a range of hydrogeomorphic conditions in the revegetation plan.

We identified five site-appropriate communities -- two riparian, two scrub-shrub, one planted wetland, and two seed mixes -- one wetland and one upland pasture based on observations of existing site vegetation, reference conditions in nearby high quality habitats, literature review (Kunze 1994), and coordination with biologists at USFWS. Detailed plant lists are included in **Tables 4-13 to 4-16**.

- **Riparian Community 1** is an Oregon ash-black cottonwood/dogwood/stinging nettle community that occurs in the overflow plain of the Columbia River and occupies a slightly higher position on floodplain terraces and natural levees along river channels. It most closely matches the riparian community described in the GLO notes. This plant community includes some limited conifers.
- **Riparian Community 2** is an Oregon ash/stinging nettle community that occurs in the overflow plain of the Columbia River between natural riverside levees and overflow lakes and ponds.
- **Willow Scrub 1** is a Columbia River-Sitka willow community that occupies seasonally flooded depressions and channel banks.

- **Willow Scrub 2** is a Pacific willow/stinging nettle community that occurs on the Columbia River floodplain behind natural levees around the margins of shallow lakes, ponds and inlets, and channel banks. It may be seasonally inundated but tolerates summer drying.
- **Planted Wetland Community** is Wapato emergent wetland community that occurs in ponds, lakes and backwater areas at a lower elevation than expanded habitat native seeded wetlands.
- **Wetland Herbaceous community** is dominated by blue wild rye and California brome.

Table 4-15 Riparian Community 1

Botanical Name / Common Name	Prevalence
TREES	
Fraxinus latifolia / Oregon ash	Dominant
Quercus garryana / Oregon white oak	Trace
Pseudotsuga menziesii / Douglas fir	Trace
Alnus rubra / red alder	Trace
Acer macrophylum / bigleaf maple	Trace
SHRUBS	
Symphoracarpos alba / snowberry	Subdominant
Sambucus racemosa / red elderberry	Subdominant
Cornus sericea / redosier dogwood	Subdominant
Crataegus douglasii / black hawthorn	Subdominant
Rosa nutkana / Nootka rose	Trace
Holodiscus discolor / oceanspray	Trace
Mahonia [Berberis] aquifolium / tall Oregon grape	Trace
Corylus cornuta / beaked hazelnut	Trace

Table 4-16 Riparian Community 2

Botanical Name / Common Name	Prevalence
TREES	
Fraxinus latifolia / Oregon ash	Dominant
SHRUBS	
Symphoracarpos alba / snowberry	Subdominant
Sambucus racemosa / red elderberry	Subdominant
Cornus sericea / redosier dogwood	Subdominant
Salix lasiandra / Pacific willow	Subdominant
Salix sitchensis Sitka willow	Trace
Rosa nutkana / Nootka rose	Trace

Botanical Name / Common Name	Prevalence
Physocarpus capitatus / Pacific ninebark	Trace
Lonicera involucrata / black twinberry	Trace
Crataegus douglasii / black hawthorn	Trace

Table 4-17 Willow Scrub Community 1

Botanical Name / Common Name	Prevalence
SHRUBS	
Salix fluviatilis / Columbia River willow	Dominant
Salix sitchensis / Sitka willow	Dominant
Cornus stolonifera / redosier dogwood	Subdominant
Spirea douglasii / spirea	Subdominant
Rosa nutkana / Nootka rose	Trace

Table 4-18 Willow Scrub Community 2

Botanical Name / Common Name	Prevalence
TREES/ SHRUBS	
Fraxinus latifolia/ Oregon ash	Subdominant
Salix lasiandra / Pacific willow	Dominant
Cornus sericea / redosier dogwood	Subdominant
Salix fluviatilis / Columbia River willow	Subdominant
Rosa nutkana / Nootka rose	Trace
Spirea douglasii / spirea	Trace
HERBS	
Carex aperta / Columbia sedge	Trace
Carex feta / green-sheathed sedge	Trace
Carex aquatilis/ water sedge	Trace
Carex obnupta/ slough sedge	Trace
Eleocharis palustris/ creeping spikerush	Trace
Juncus tenuis / slender rush	Trace

4.14.2 USFWS Maintenance and Management Considerations

Revegetation plans are under development in coordination with USFWS to understand and incorporate their management and maintenance activities. The Refuge is managed for a wide range of species that require a broad set of habitats. Avian species include purple martin, northern harrier, and waterfowl including Canada geese.

Specific focal conservation targets for Steigerwald NWR are included in the Comprehensive Conservation Plan for the Ridgefield NWR Complex (USFWS, 2005). The focal conservation target objectives provided a useful point-of-reference for the revegetation types and areal extents and include:

- Wetland Complex
    - CCP Objective 1.1, maintain up to 237 acres of wetland
- Riparian System
    - CCP Objective 1.2, restore 122 acres of riparian bottomland forest
    - CCP Objective 1.3, restore 101 acres of riparian scrub-shrub
- Oak Woodland and Oak Savanah
    - CCP Objective 1.4, maintain 41 acres of oak woodland
    - CCP Objective 1.5, initiate planting of oak savannah on 93 acres of grassland
- Grasslands
    - CCP Objective 1.6, maintain short (3- to 6-inch) perennial grass as winter forage on 168 acres (71 acres as unmowed field)

Active management at the Refuge is accomplished by refuge staff, cooperative farmers, and friends' groups. This management includes mechanical removal and herbicide application using boom and backpack sprayers as well as mowing, haying, and grazing. These activities help manage invasive reed canary grass and Himalayan blackberry and maintain grazing habitat for Canada geese. Large open areas will need to be maintained in the revegetation plan to provide desired habitat conditions and facilitate ongoing management using large farm equipment.

4.14.3 Proposed Revegetation Priorities and Methods

The first revegetation priority is to plant or seed all areas on the site that will be temporarily disturbed during construction. Disturbance activities include:

- Levee borrow excavation, expanded habitat excavation, and channel excavation;
- Road embankment, elevated channel, parking lot, and levee removal;
- Levee, levee overbuild, and wave break material placement; and
- Construction-related disturbances from hauling.

The riparian communities will be planted along the natural levee of the Columbia River (including borrow areas) and along the deeper floodplain channels. This approach will help establish a wide (approximately 300-foot) riparian buffer along the Columbia and provide shade and a future source of large wood to newly constructed floodplain channels. These plantings will also be included on the levee overbuild and the Gibbins Creek alluvial fan.

Willow scrub communities will be planted along shallow floodplain channels and some scalping areas. The remaining scalped areas will be planted with wetland seed. One wetland planting area has been identified to be graded to a lower elevation to ensure removal of reed canary grass and will be planted with wetland plugs for additional plant community diversity. New levees will be seeded with an upland mix. Selective screening using native plant material is also needed adjacent to the proposed parking lot.

To reduce construction cost, plant material will be live stakes, rooted cuttings, and seed. Tractor isles will be incorporated into the planting layout to facilitate mechanical maintenance where appropriate.

4.14.4 Invasive Species Management

Prior to and after planting, invasive species, such as reed canary grass and Himalayan blackberry would be treated through mechanical and chemical means to reduce their densities. Increased inundation due to reconnection of the site to the Columbia River and localized scalping will further impede invasive cover and allow native plantings to establish. In undisturbed (non-graded) zones where Riparian plant communities are proposed, existing ground cover of pasture grass will remain, to minimize the creation of bare ground areas. Woody plant material will be pocket planted into existing conditions.

Suitable beaver habitat would be encouraged by providing increased quantity and quality of forage and dam-construction material. The design currently includes numerous wood habitat structures at locations particularly along Channel 3 (Gibbons Creek south) where they, if utilized by beaver, would impound water and increase soil saturation, forming pools and emergent wetlands.

4.15 Conservation Measures

Although the overall project is intended to benefit ESA-listed species and fish and wildlife habitat, short-term adverse effects may occur during project construction. In order to minimize these short-term impacts the following best management practices (BMPs) and conservation measures will be implemented during the design and construction of the project.

Conservation measures identified for this project are those included within Bonneville Power Administration's (BPA) Habitat Improvement Program (HIP) III Biological Opinions issued by NMFS (2013) and USFWS (2013b) and outlined in BPA's HIP III Handbook (2014). The HIP III Handbook lists out general aquatic conservation measures applicable to all project actions as well as conservation measures for specific project actions. General aquatic conservation measures are listed out on sheet s G1.2 and G1.3. **Table 4-19** below provides the list of specific project actions proposed for the Steigerwald project that will be covered under HIP III. The general aquatic conservation measures and specific project action conservation measures were reviewed and incorporated into the 30% design.

Table 4-19 Conservation Measures

HIP III Action	Action Description
Fish Passage – 1a	Dams, water control, or legacy structure removal
Fish Passage - 1f	Bridge and culvert removal or replacement
River, Stream, Floodplain, and Wetland Restoration – 2b	Set-back or removal of existing berms, dikes, and levees

HIP III Action	Action Description
River, Stream, Floodplain, and Wetland Restoration – 2d	Install habitat-forming material instream structures (LWD, boulders, spawning gravel)
River, Stream, Floodplain, and Wetland Restoration – 2e	Riparian vegetation planting
River, Stream, Floodplain, and Wetland Restoration – 2f	Channel reconstruction
Irrigation and Water Delivery/Management Actions – 7g	Install new or upgrade/maintain existing fish screens

5 CONSTRUCTION

5.1 Opinion of Construction Costs

Construction is planned to begin in 2019. A probable opinion of construction costs has been developed for budget planning purposes and for comparison with construction contractor bids. The cost estimate is based on recent bid experience with stream and wetland restoration and levee construction projects, relevant WSDOT bid results, and conversations with construction contractors in Southwest Washington.

Primary unit cost and other assumptions include:

- **Mobilization**: 6% of all other direct costs.
- **Temporary work zone traffic control**: Traffic control will be significant at times during construction, including full road closure on SR 14 during construction of the Levee Closure Structure immediately west of the SR 14/Gibbons Creek bridge. A detour route will be utilized during this time. Less significant traffic control measures including signage and flaggers will be required for trucks entering the roadway and for construction equipment moving between work areas south and north of SR 14. The estimated cost of Project Temporary Traffic Control is computed as the sum of traffic control related items from the cost estimate provided by KPFF.
- **Erosion and Sediment Control**: Erosion and sediment control is assumed to include silt fence or straw wattle at the downslope sides of excavations areas where adjacent to wetlands, turbidity curtains installed at the channel connections to the Columbia River, check dams on all new channels. Erosion seeding is included on all excavation and fill areas, and the seed mixes are listed in the revegetation plans.
- **Demolition**: The largest items to be demolished include the Gibbons Creek diversion structure near the SR 14 Bridge and the Gibbons Creek fish ladder and culvert at the confluence with the Columbia River. These include removal and disposal of the concrete and steel elements. Additional culverts will be removed while removing the elevated canal and mid-site berm/road.
- **Relocated parking lot, visitor facilities, and art**: Relocating the existing parking lot, visitor facilities, and art installations will require significant demolition and salvage operations. Relocated features include the manual and automatic gates, decorative boulders, restrooms, interpretive signage and kiosks. The existing visitor center area has electrical and telecommunications service, which will be restored to the new visitor center area. Water service and irrigation will not be installed at the new visitor center area. The existing visitor area and art trail includes approximately numerous pieces of art and interpretive features that will require careful handling to remove, reinstall, or relocate to a designated USFWS location.
- **Clearing and Grubbing**: Clearing and grubbing will be required in many areas to remove vegetation and organic material from the top layer of excavated soil, prior to using excavated

material for levee embankment. The estimated cost of Clearing and Grubbing is 1.0% of all other direct costs.

- **Earthwork**: Earthwork accounts for approximately half of the total project construction costs, including excavation activities (channel excavation, habitat expansion grading, levee and berm removal, borrow excavation, trail grading) and embankment activities (levee construction, wave break embankment, trail grading, restoring the borrow area).

  We assume the majority of earthwork will be completed by large scrapers, large excavators, and off-road dump trucks. The anticipated work rate of 2 sets of 6 scrapers each is estimated at approximately 20,000 CY per day. Finish grading of channels and slopes will be completed by bull dozers and backhoe excavators. We estimate the cost of excavation to be $3-$4/CY, plus an additional cost of $3-$4/CY for embankment or placement of excavated materials. This estimate assumes efficient work with little to no re-handling and amendment of soils.

- **Levee Construction**: Levee construction will include preparation of the levee foundation, placement of geogrid at the base of the levee fill, embankment and compaction of suitable levee fill material, use of less suitable materials in the wave break overbuild slopes adjacent to the levees to reduce the need for rip rap slope protection, and construction of a gravel access road on top of the levee.

- **Interior Drainage Structure**: A drainage structure will be constructed within the eastern setback levee to provide drainage for the James property to the east. This structure will include a culvert pipe with tidegate, concrete wing walls, manual canal gate and gate vault, pump station, force main piping, and electrical power from a nearby utility pole on the private property.

- **Stream diversions**: Management of Gibbons Creek flows will be a critical element of project sequencing. The existing elevated canal provides a built-in stream bypass system that will remain in place until the new Gibbons Creek channel is completed. It will be necessary to divert Gibbons Creek into a temporary stream channel north of SR 14 for construction of the new channel and flood wall. Additional work area isolation will likely be required when working in and around the channels and ponds within the Refuge. We estimate this cost to be approximately $50,000.

- **Pedestrian Trail and Bridges**: After removal of the southern levee along the Columbia River, a new gravel pedestrian trail will be constructed to replace the levee-top trail. Two bridges will be required to cross High Flow Channel #2 and the new Gibbons Creek channel. The existing Gibbons Creek channel and High Flow Connection Channel #4 will be crossed using at-grade stream fords to eliminate the need for bridges. The two proposed bridges will be prefabricated bridges with guardrails installed on concrete abutments.

- **Civil/Roadway improvements**: Proposed improvements related to the SR 14 roadway and right-of-way include the roadway prism raising, striping removal and painting, pavement planning, repaving with hot mix asphaltic concrete, centerline rumble strip, guardrails, impact attenuators, and wire fencing and gate near the SR 14 Bridge.

- **Gibbons Creek Flood Wall North of SR 14**: The proposed flood wall will be a reinforced concrete T-type structure along the west side of Gibbons Creek, extending from the north end of the SR 14 closure structure approximately 800 feet north. The proposed wall height is EL. 45.7'.

- **Closure Structure across SR 14**: This closure structure will serve as the flood wall across SR 14, extending 73 feet between the levee abutment wall to the south and Gibbons Creek flood wall to the north. The structure will be a permanent concrete strip foundation, with steel sockets that will receive portable steel flange posts. Portable reinforced concrete panels will be erected prior to a flood event.

- **Surveys**: We anticipate the majority of channel layout and grading will be performed by the Contractor using GPS guided construction equipment. Traditional construction surveying and staking will be required at the new parking lot and for the setback levee alignments. We estimate this cost to be approximately $80,000.

- **Revegetation**: these costs reflect a moderate level of effort including approximately 1 acre of ornamental planting/screening near the parking lot, over 100 acres of native plantings for riparian habitat and willow scrub habitat, and approximately 200 acres of seeding in wetlands, pasture areas, and on levee side slopes.

- **Wood habitat structures (large wood)**: reflects a modest amount of wood placement in channels and floodplain habitats throughout the site. These bid items are per each structure, and each structure has an average of 2 to 3 logs. There will be an estimated 600 logs installed at approximately $400 to $800 per log. This estimate assumes a relatively low cost for obtaining the logs.

- 2019 material and labor costs and prevailing wages are also assumed.

- A design contingency of 12% is assumed for design changes and additions such as additional erosion control measures and/or changed/additional levee, road, structural, or habitat measures that may be required after permitting and resource agency reviews. This also includes cost escalation to 2019 and 2020.

Considering these assumptions, the total construction cost estimate is approximately $20,081,000. A summary cost estimate is shown in **Table 5-1**. Detailed construction cost estimate is included in **Appendix H.**

Table 5-1 Summary of Estimated Construction Costs

Item		Cost
Site Preparation (Mobilization, Surveying, Clearing, Demo)		$1,274,600
Earthwork - Channels, Expanded Habitat Trails (NON-levee)		$5,288,800
West Setback Levee		$3,229,700
East Setback Levee		$1,262,500
Drainage		$280,600
Closure Structure		$88,600
Levee Abutment Wall		$47,200
Flood Wall		$553,000
Trails & Bridges		$1,288,000
SR 14 Roadway Raising & Resurfacing		$647,500
Traffic Control Measures		$183,000
Erosion Control		$204,500
Planting		$1,707,700
Relocation of Parking Lot, Visitor Facilities, Interpretive		$180,100
Wood Habitat Structures		$389,400
Direct Construction Subtotal		$16,677,886
WA State Sales Tax	8.4%	$1,400,942
Design Contingency	12%	$2,001,346
TOTAL PROJECT COST		**$20,081,000**

5.2 Construction Specifications

Construction specifications will follow the standard WSDOT construction specifications format. The project will require the following special provisions, broken down by WSDOT specification division:

Division 1 General Requirements

- 1-05.4 Conformity with and Deviations from Plans and Stakes
- 1-07.15 Temporary Water Pollution Prevention
- 1-09.7 Mobilization
- 1-10 Temporary Traffic Control

Division 2 Earthwork

- 2-01 Clearing, Grubbing, and Roadside Cleanup
- 2-02 Removal of Structures and Obstructions
- 2-03 Roadway Excavation and Embankment
- 2-06 Subgrade Preparation
- 2-09 Structure Excavation
- 2-12 Construction Geosynthetic

Division 4 Bases

4-04 Ballast and Crushed Surfacing

Division 5 Surface Treatments and pavements

5-04 Hot Mix Asphalt

Division 6 Structures

6-01 General Requirements for Structures
6-02 Concrete Structures
6-03 Steel Structures
6-11 Reinforced Concrete Walls

Division 7 Drainage Structures, Storm Sewers, sanitary Sewers, Water Mains, and Conduit

7-02 Culverts
7-05 Manholes, Inlets, Catch Basins, and Drywells
7-08 General Pipe Installation Requirements

Division 8 Miscellaneous Construction

8-01 Erosion Control and Water Pollution Control
8-02 Roadside Restoration
8-06 Cement Concrete Driveway Entrances (KPFF)
8-08 Rumble Strips
8-09 Raised Pavement Markers
8-11 Guardrail (KPFF)
8-12 Chain Link Fence and Wire Fence
8-15 Riprap
8-17 Impact Attenuator Systems
8-20 Illumination, Traffic Signal Systems, Intelligent Transportation Systems, and Electrical
8-21 Permanent Signing
8-22 Pavement Marking
8-23 Temporary Pavement Markings

Division 9 Materials

9.00 Definitions and Tests
9-01 Portland Cement
9-02 Bituminous Materials
9-03 Aggregates
9-04 Joint and Crack Sealing Materials
9-05 Drainage Structures and Culverts
9-06 Structural Steel and Related Material
9-07 Reinforcing Steel
9-08 Paints and Related Materials
9-09 Timber and Lumber

9.13 Riprap, Quarry Spalls, Slope Protection, and Rock for Erosion and Scour Protection and Rock Walls
9-14 Erosion Control and Roadside Planting
9-16 Fence and Guardrail
9-21 Raised Pavement Markers (RPM)
9-26 Epoxy Resins
9-28 Signing Materials and Fabrication
9-33 Construction Geosynthetic
9-34 Pavement Marking Material
9-35 Temporary Traffic Control Materials

Special Provisions

Construction Surveying
Earthwork and Levee Construction
Pump Station
Test Fills and Instrumentation
Wood Habitat Structures
Revegetation
Work Area Isolation Plan

5.3 Construction Sequencing and Contingency Plan

5.3.1 Construction Sequencing

The Steigerwald project will require large sources of borrow material to construct the two proposed setback levees. The total length of new levee will be approximately 7,400 feet. Identification of areas for potential borrow sources for fill material within the proposed restoration limits is being accomplished through examination of test pits scheduled through the design phase. Adequate and economical fill may be limited due to high groundwater, wet or saturated soils and, in some areas soil that is too coarse to use in levee construction. The preferred borrow source is the existing levee embankment material, which consists of fine sands located above the groundwater table. This will provide a known reliable source of material for the base of the setback levees that is accessible and suitable under a broader construction season when interior soils may be saturated. Accessing large sources of suitable material on site minimizes the required construction period.

Levee Construction Sequencing

Levee construction is planned for one season, beginning in the spring of 2020 which is the second year of construction. Construction will begin with building the levee crests to the FEMA standard for certification (3 feet above the 100-year water level, approximately elevation of 40 at the east levee and 39 at the west levee). The existing levee would be removed concurrently with the new levee construction and only down to this same FEMA elevation. Thus, flood risk reduction levels at all locations would be maintained at the FEMA base flood protection standard at all locations during construction.

Benefits of using the existing levee embankment as a borrow source include:

- The existing levee material consists of fine sand that would be less dependent on weather conditions for placing and compaction.
- The existing levee embankment is placed on higher ground and above the groundwater table. This material is unlikely to be wet or saturated and need moisture conditioning to achieve optimum water content.
- Using the existing embankment soils will provide an optimal route for construction equipment to remove, haul and place fill material at the new setback levee locations.
- Each of the above factors would help to lower construction costs through improved work efficiency.
- The ability to use existing levee material would reduce impacts to the site by limiting the sizes of borrow areas or limit the amount of time borrow areas are without vegetation. These would reduce impacts to sensitive habitats and wetlands.

Construction sequencing is summarized on Plan Sheet G1.4 in **Appendix A** and in Table 5-2 below. The key factors influencing the construction sequence are:

- Identifying work that only can be conducted within the in-water work window (June 1 – October 15);
- Ensuring that both the eastern and western setback levees are constructed in the same season as removal of the existing levee to maintain flood risk reduction levels for the surrounding communities;
- Obtaining sandy fill material from the upper several feet of the southern levee to provide ideal fill for use in the foundation lifts of the setback levees;
- Obtaining suitable levee fill material from channel excavation and habitat expansion grading areas;
- Completing the bulk of the excavation and fill activities during one season, utilizing large scrapers, to maximize efficiency and minimize excavation unit prices;
- Construction of the new Gibbons Creek channel and connection to the Columbia River almost completely prior to removing the elevated canal; and

Table 5-2 General Construction Sequence.

YEAR 1
1. Construct new parking lot west of west levee.
2. Construct levee test fills, and collect settlement data to guide levee construction in season 2.
3. Construct Gibbons Creek North of SR14 (Hickey pedestrian bridge, flood wall and berm along the creek, and floodwall abutment north of SR 14).
4. Construct closure structure near SR14 bridge.
5. Raise, Stripe, and pave SR14.
(Note that order of work in year 1 may vary at contractor discretion.)

YEAR 2
1. Remove old refuge parking and stockpile art elements for relocation. This allows use of the lot during the winter between seasons if desired.
2. Construct setback levee foundation using borrow from existing levee. Scrape down south levee to (elev. 39 ft. NAVD88) and use sandy fill material for setback levee foundations.
3. Stop borrow from existing south levee when crest elevation is lowered to the FEMA standard. Maintain FEMA standard at all times during construction.
4. Construct habitat expansion areas, channels (including wood structures), and use suitable fill for levee construction.
5. Construct setback levees to FEMA standard. Complete all levee segments to this standard prior to building any individual segment higher.
6. Remove remainder of south levee and continue construction of setback levees.
7. Divert Gibbons Creek from elevated canal to new channel.
8. Remove elevated canal and diversion structure, use material to finish levee overbuild or where otherwise needed.
9. Remove Gibbons Creek fish ladder and culvert, and excavate channel 1 breach after levee construction, allowing use of this crossing as a levee earthwork haul route.
10. Construct trails and bridges.
11. Demo central access road.
12. In construction year 3 (2021), survey levees for settlement and place fill to raise embankment to minimum grades if necessary.
(Note that order of items 10 and 11 may vary at the contractor's discretion.

5.3.2 Interim Flood Protection

General

High water conditions from the Columbia River, Gibbons Creek, or Interior drainage may occur during construction. Plans and specifications for the proposed work will address measures to maintain the integrity of the combined existing and set back levee system during these periods. Temporary (during construction) mitigation measures include dewatering, construction of setback levees to the FEMA standard prior to lowering the existing levee below this elevation. Sandbags and pumping can also be used to supplement the effort.

Work within the levee-protected areas above ordinary high water will be conducted as weather allows from March through November. Work below ordinary high water will occur within the approved in water work window.

Dewatering

The dewatering plan will address interior drainage and overflows from Gibbons Creek. When setback levee construction proceeds during high water, the dewatering system should be capable of maintaining the groundwater levels to minimum depth of 2 feet below the bottom of the excavation for the base fill layer of the levees. At least one piezometer must be installed near the low point of excavation for each levee to monitor the piezometric level. If this level cannot be maintained, provision must be made in

the plans to delay fill placement until this level can be maintained.
Prior to construction of the west levee the Port pumps can utilized to lower groundwater levels, and the Refuge water control structures can be opened to drain the channels and lakes. After the West levee construction has started excess flows shall be pumped over the levee to high ground and filtered before release to existing wetlands. Clean water may be pumped to the Gibbons Creek elevated canal.

Setback Levee Construction to the FEMA Standard
As described in the construction sequence section above, the setback levees will be constructed to the FEMA standard (base flood elevation plus freeboard 39 to 40 feet NAVD88) prior to excavation of the existing levee below this level. This will maintain FEMA requirements for adjacent properties throughout the construction period. It also ensures that satisfactory impervious material and construction access is available to build the setback levees.

Setback Levees at Full height prior to Channel Completion
Channel connections to the Columbia River will be completed after all low lying interior grading elements are completed. Removal of the elevated canal and diversion infrastructure will occur after the Gibbons channel connection with the Columbia River, and the fill will be used as overbuild and upland habitat refugia.

5.3.3 Construction Contingency Plan

The contingency plan will guide actions taken in case of high river levels during the construction period. The intent is to minimize risks of construction delays, minimize overall construction duration, and maintain health and safety conditions on site and for neighboring properties. The contingency plan will include proposed measures to protect areas subject to temporary reduced levels of protection due to construction activities. The river stage will be monitored weekly during construction, and the river elevation at which the contingency plan will be activated when Columbia River stage is proposed to be 36 feet NAVD88, two feet below the temporary minimum levee crest elevation described in Section 5.3.1.

Table 5-3 Construction Contingency Plan.

Risk Item	Probability / consequence	Construction Phase	Contingency Measures
Prior to construction Flood stage from the Columbia River projected to reach 36 ft during construction season	Very low / high	Prior to existing levee removal	Delay scrape down until WSE are below and projected to remain below 36ft
During Construction Flood stage from the Columbia River projected to reach 36ft.	Low/high	Combined existing and set back levees at 39 ft	Combined setback and existing levee protection at or above 39ft: stockpile sandbags emergency flood protection sufficient to raise low spots to 2 ft above projected stage
Flood stage from the Columbia River projected to reach 37 ft or more	Low/high	Combined existing and set back levees at 39 ft	Install additional flood control measures to elev 2ft above projected stage

Risk Item	Probability / consequence	Construction Phase	Contingency Measures
Existing levee scrape down to finish grade	med/med	Setback levees 39 ft or higher	Keep existing levee crest 2 ft above projected river stage until final channel connections
Gibbons Creek exceeds elevated canal capacity	Low/high	Grading below diversion elev. 30 ft	Delay construction below in ponded areas until flows recede and initiate dewatering plan
Habitat scrape down material too wet for levee construction	Low/high		Use Port pumping station to prevent ponding; Use upland refugia fill areas to dry soils to required soil moisture content

5.4 SR 14 and Closure Structure Phasing

A three-stage construction staging plan is initially proposed for construction of the closure structure across SR 14. The staging plan is shown on sheet R6.1 in the Construction Drawings (**Appendix A**). The staged construction is intended to keep one lane of traffic open in each direction at all times, while construction of the closure occurs in the other lane. It may be possible and/or desirable from WSDOT's perspective to construct the closure using a full road closure and detour route; this can be easily accommodated as the design progresses.

We will need concurrence from WSDOT that either one-foot wide shoulders or 10-foot wide travel lanes are acceptable during temporary traffic control since these widths are below their standards. If WSDOT does not approve of these widths, either a full closure of SR 14 with detour or continuous flagging will be required during construction. If required, the construction detour would use the same route as required for the flood event detour. The detour route in both cases would be partially located inside the Washougal city limits and partially located within Clark County's boundary. Therefore, coordination with these jurisdictions and WSDOT is required to obtain an agreement for the use of the detour route during the flood event and possibly during construction as well.

5.5 Cut and Fill Quantities

In order to identify which construction activities to prioritize for Season 1, we performed the following analysis of cut-fill accounting to ensure that suitable fill material would be available for levee construction. The material from all excavation areas is divided up into layers based on depth from the existing ground surface and relation to the anticipated water table at 21 feet NAVD88. This analysis assumes the following:

- Excavated material within one foot of the existing ground surface will be unsuitable for levee fill due to vegetation and organic content.
- Excavated material within one to three feet below the surface is identified at topsoil, but this material would also be suitable for levee fill.
- Excavated material below three feet from the existing grade surface but above the anticipated water table would be suitable for levee fill.

- Excavated material below the anticipated water table (21’ NAVD88) will likely be saturated and unsuitable for levee fill.

The cut-fill accounting for construction of the project is shown below in **Table 5-4**.

Table 5-4 Construction Cut and Fill Summary.

Cut or Fill	Item/Activity	Total (CY)	Strippings Top 1'	Usable for Levee Topsoil (1-3')	Usable for Levee Middle (above 21')	Unsuitable Below 21'
Cut	Excavate Gibbons Creek North of SR 14	6,700	1,000	2,000	1,700	2,000
Cut	Excavate Channel #1	7,410	2,398	4,646	4,548	-
Cut	Excavate Channel #2	114,430	10,297	18,678	31,104	28,382
Cut	Excavate Channel #3 (Gibbons S w/ Benches)	308,250	23,274	42,948	85,928	89,642
Cut	Excavate Channel #4	24,715	5,354	7,196	13,709	828
Cut	Excavate Channel #5 (Gibbons Creek North)	13,070	1,000	2,744	980	1,000
Cut	Excavate Channel #5 (Gibbons Creek North SR14)	7,550	-	-	-	-
Cut	Habitat Expansion Grading (Approx 105 ac)	340,052	-	-	-	-
Cut	Excavate to Remove Elevated Canal	68,220	7,000	-	60,000	-
Cut	Excavate to Remove Berm/Road Mid-site	14,700	5,000	-	9,700	-
Cut	Trail Grading - Excavation (Cut)	16,900	4,000	-	12,900	-
Cut	Existing Levee Removal	199,560	25,000	-	174,560	-
	Excavation (cut) Subtotals	**1,121,557**	**84,323**	**78,212**	**395,129**	**121,852**
Fill	West Setback Levee Embankment	377,800	-	-	377,800	-
Fill	West Setback Levee-extra to account for settlement	73,000	-	-	73,000	-
Fill	West Levee Overbuild 8:1 slope	83,535	-	7,000	3,000	97,000
Fill	East Setback Levee Embankment	124,240	-	-	124,240	-
Fill	East Setback Levee-extra to account for settlement	21,000	-	-	21,000	-
Fill	East Levee Overbuild 8:1 slope	18,070	-	2,000	-	22,000
Fill	Fill Existing Gibbons Ck North of SR 14	1,839	1,000	2,000	1,700	2,000
Fill	SR-14 road raise embankment	6,500	-	-	6,500	-
Fill	Trail Grading - Fill ramps	6,280	-	-	3,950	-
Fill	Levee turnouts and access ramps	50,000	-	-	20,000	-
Fill	Well Field area fill to EL 39	52,470	-	-	20,000	-
Fill	Upland Habitat - total	160,825	-	-	-	-
Fill	East Levee Fill Area	47,350	-	-	-	-
Fill	Topsoil Placement	-	-	67,212	-	-
	Embankment (fill) Subtotals	**1,031,383**	**1,000**	**78,212**	**651,190**	**121,000**
	TOTAL PROJECT - Shortfall (-) OR Excess (+) =	**90,174**	**83,323**	**-**	**(256,061)**	**852**
	TOTAL PROJECT CUT =	1,121,557				
	TOTAL PROJECT FILL =	1,031,383				
	EXCESS FILL MATERIAL TO BE DISPOSED OF (ONSITE) =	90,174				

5.6 Access Roads

The Refuge has a network of existing access roads throughout the site. The contractor will likely utilize the existing access roads along the Gibbons Creek elevated canal and the existing levee, as well as the existing north-south oriented access road in the middle of the site. At the outset of the project, the contractor will establish a circuit to allow for efficient movement of the scraper excavators, excavating material from the channel and habitat expansion areas and transporting fill material to be placed at the setback levees.

Many of the existing and temporary access roads will be decommissioned at the end of construction. The setback levees will include a permanent gravel access road at the levee top. The levee access road/trail will be replaced with a new gravel road/trail along the Columbia River, including two bridge crossings. The bridges will be designed to pedestrian and equestrian loads and to accommodate light emergency access vehicles such as all-terrain vehicles (ATVs).

6 FUTURE PROJECT PLANS & REVIEWS

Several project maintenance and management plans and reviews will be developed for the restoration project. These will be completed after the 30% Design phase.

6.1 Water Control Plan

USACE Section 408 team members have confirmed that a Water Control Plan would not be required for this project. No water control structures are included in the proposed project.

6.2 Operation and Maintenance Plan

The Port of Camas-Washougal (2012) has developed an operations and maintenance (O&M) plan for the existing Washougal Flood Damage Reduction System. This manual outlines the O&M of the Port's Levee System, which is under the jurisdiction of the Port. With the proposed modification of this levee system, this O&M plan will be updated to meet the USACE Section 408 requirements. The updated plan will identify O&M requirements needed throughout the life of the proposed alteration and identify the responsible entity for O&M into the future. The O&M plan will also include emergency response procedures.

The Port has agreed to maintain jurisdiction and responsibility for O&M of the flood damage reduction system including proposed modifications to the system such as, maintaining and installing the proposed closure structure.

6.3 Monitoring/Adaptive Management Plan

A Monitoring and Adaptive Management Plan will be developed for the project. The purpose of this plan is to capture the ecological impacts for the restoration actions and to collect necessary data to adaptively manage the project in the future. This plan will ensure that project effectiveness will be monitored at the site by linking measurable metrics to project goals and objectives.

The Monitoring/Adaptive Management Plan will list out objectives, monitoring schedule, monitoring protocols, data analysis, and a quality assurance plan.

6.4 Independent External Peer Review

An Independent External Peer Review (IEPR) of the 60% and 90% design packages will be conducted after completion of each respective USACE District Agency Technical Review (ATR). The IEPR will be performed by an independent contractor that meets the qualifications for the review of the project (USACE 2014a).

As part of the IEPR a Safety Assurance Review (SAR) Plan was developed to provide the review charge to the IEPR contractor. The SAR plan has been submitted for approval by the USACE to ensure that the plan reflects a level of review commensurate with the scope and scale of the proposed actions. The purpose of the IEPR and SAR is for an independent and impartial review of the adequacy, appropriateness, and acceptability of the proposed design and construction activities for the purpose of assuring public health, safety, and welfare.

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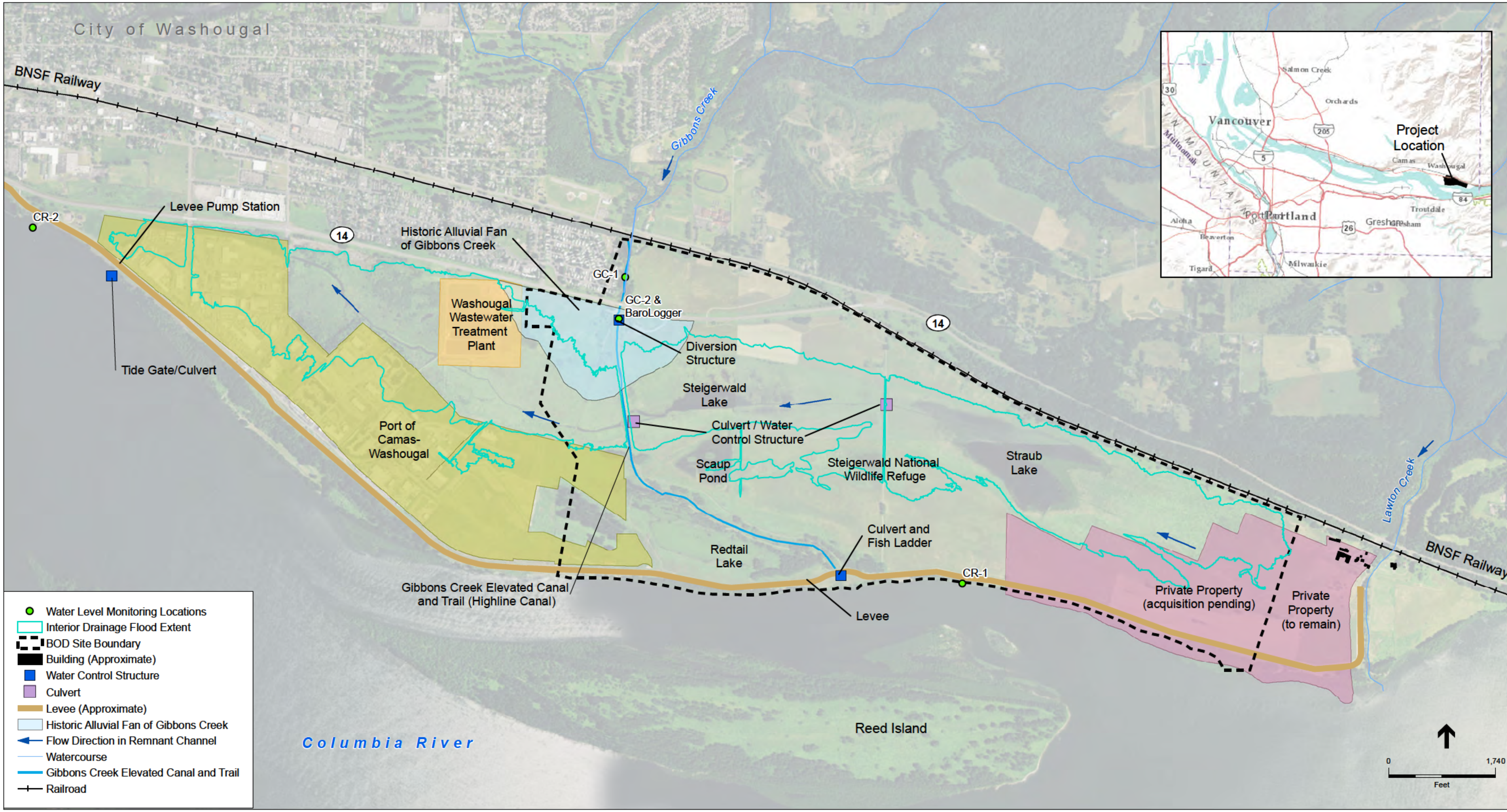
FIGURES



SOURCE: Estuary Partnership, 2013; Clark County; National Hydrography Dataset; USACE LiDAR, 2010
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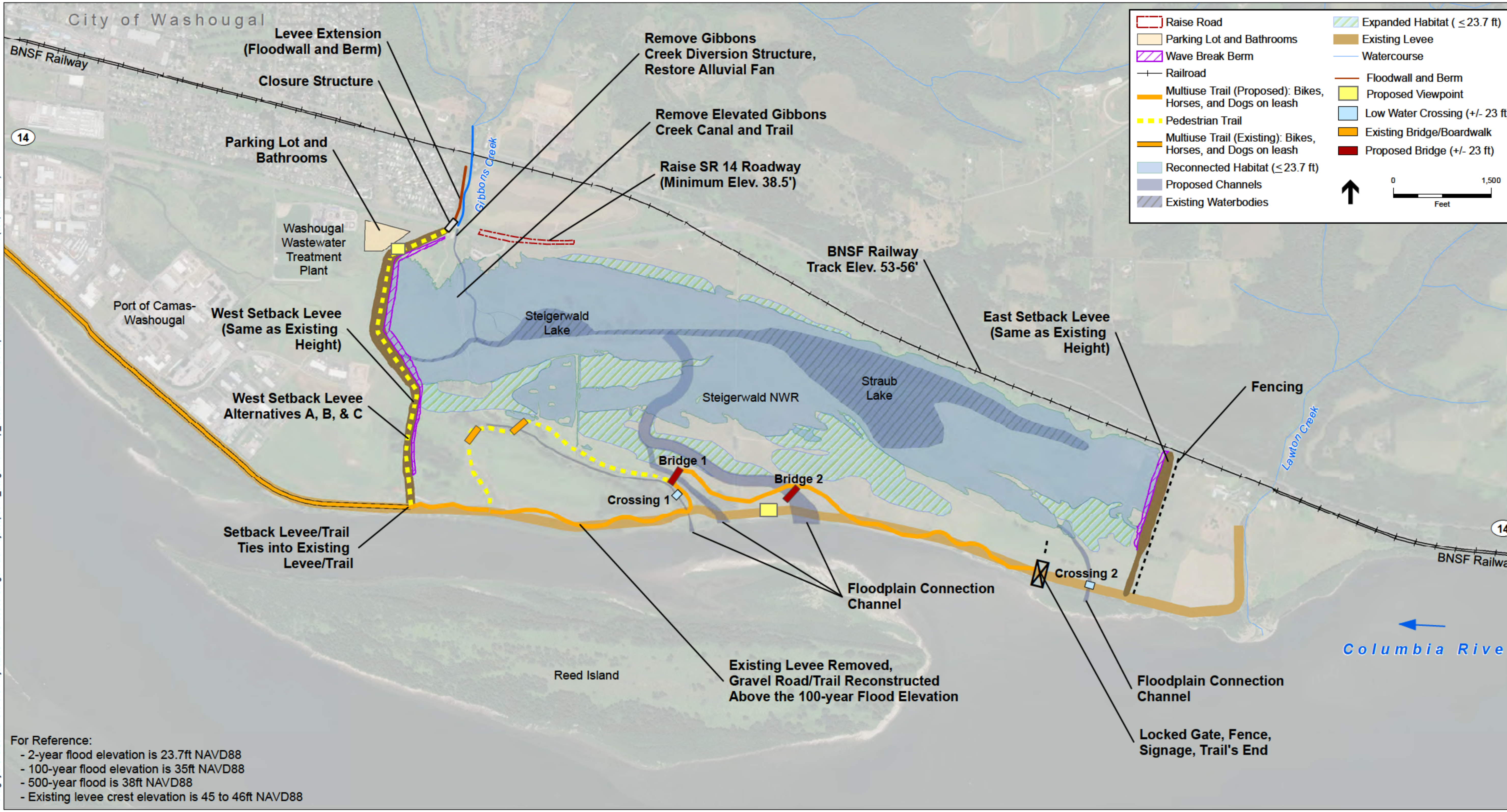
Sources: Esri, DeLorme, USGS, NPS
Sources: Esri, USGS, NOAA

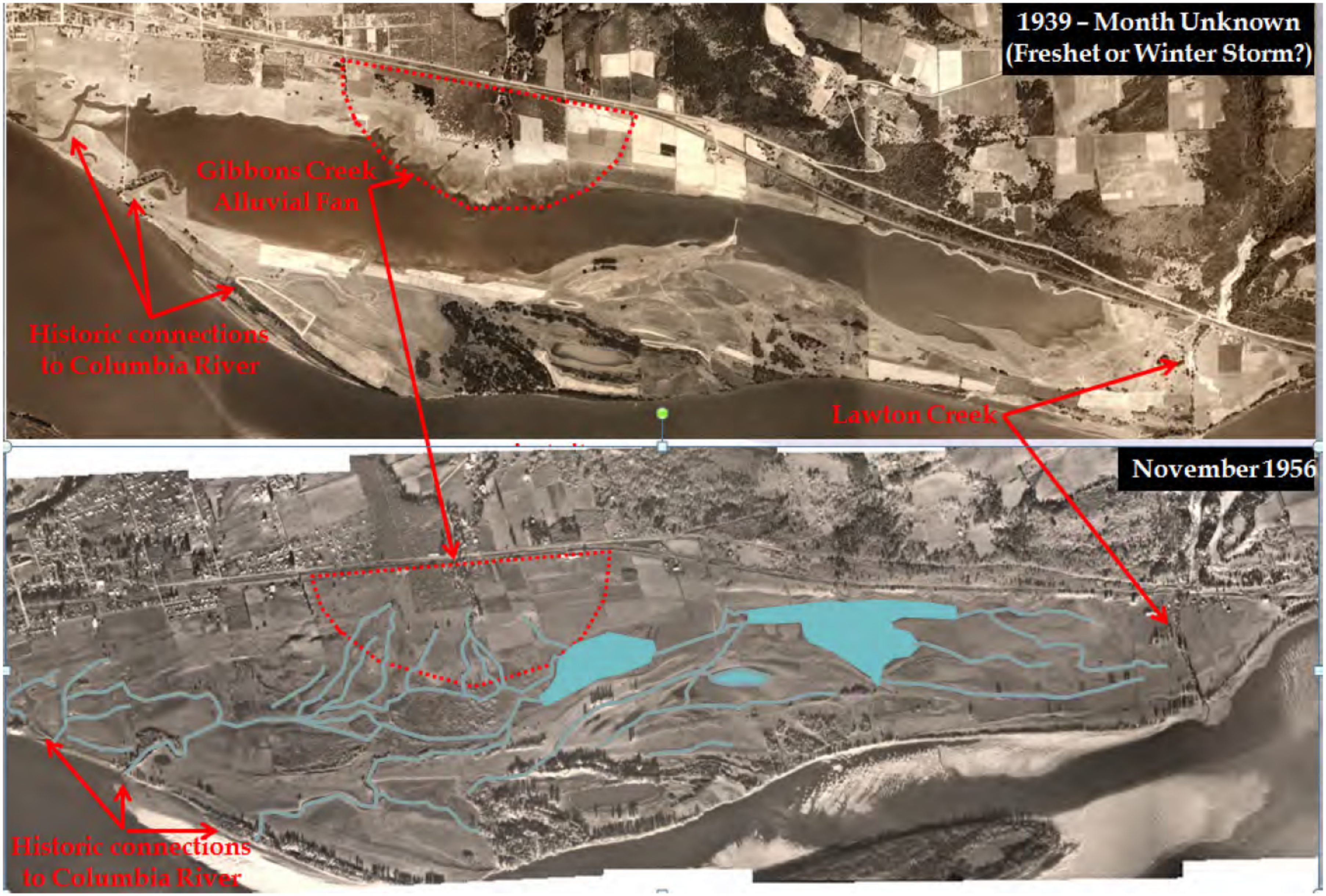
Figure 1-1
Existing Site Conditions at Steigerwald National Wildlife Refuge
Washougal, Washington



Steigerwald Restoration Design

SOURCE: Estuary Partnership, 2013; Clark County; Na ional Hydrography Dataset; USACE LiDAR, 2010
Service Layer Credits: ESRI 2013

Figure 1-2 - Site Plan
Proposed Floodplain Restoration Overview
Washougal, Washington

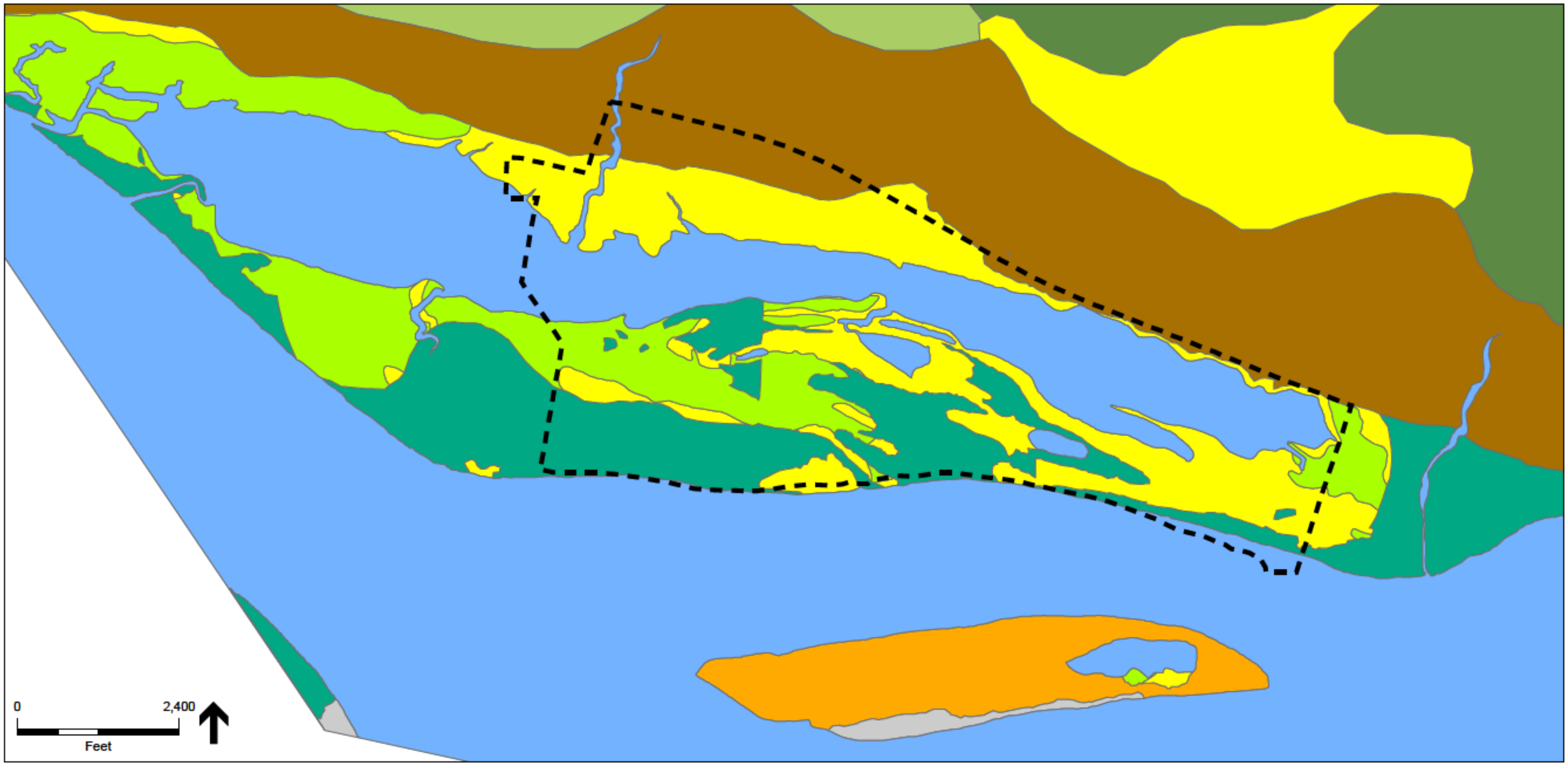


Source: Estuary Partnership 2014

Steigerwald Restoration Design.

Figure 2-1

Historic Conditions at the Steigerwald National Wildlife Refuge.



Historical GLO Map, Steigerwald Area, Author: John Christy, Oregon Heritage Institute

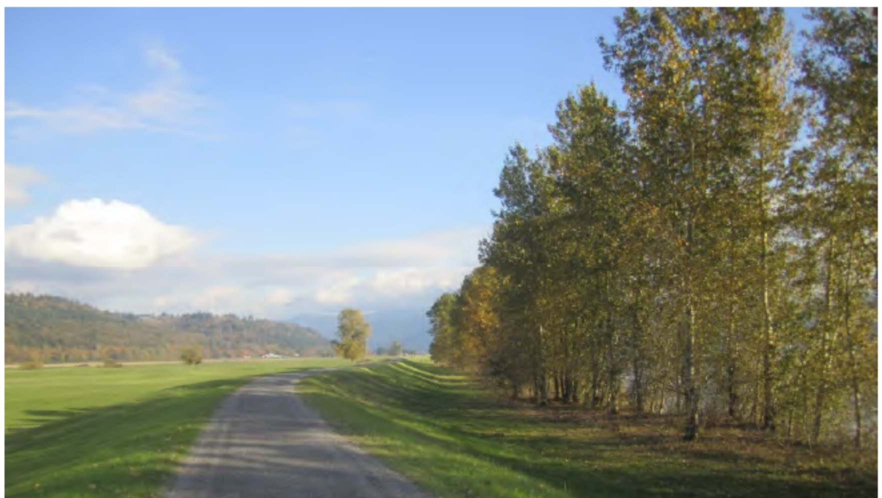
- Site Boundary
- Prairie: Dry upland prairie on steep or gentle slopes, or tops of ridges. May have scattering trees, most with distances from corners > 100 links, and inclusions of woodland or savanna. Understory unspecified or with references to abundant grass.
- Prairie: Seasonally or perennially wet prairie.
- Riparian and Wetland Forest: Ash-mixed deciduous riparian forest with combinations of red alder, bigleaf maple, black cottonwood, white oak, dogwood, Conifers may be present in small quantities.
- Shrubland: Willow swamp, sometimes with ninebark, including riparian stands on gravel or sand bars. May contain small amounts of ash.
- Unvegetated: Sand bar and sandy barrens
- Upland Forest: Burned Doug Fir forest, often with scattered trees surviving fire.
- Upland Forest: Douglas fir-white oak (bigleaf maple) forest, with brushy understory of hazel, young oak, oak brush, oak sprout bracken, briars, sometimes willow.
- Upland Forest: Douglas fir forest, often with bigleaf maple, grand fir, dogwood, hazel, yew. No other conifers present. No Oak.
- Water and Wetlands

Source: Oregon Heritage Ins itute

Figure 2-2
GLO Map of the Steigerwald Area c.1860s

Riparian trees dominated by black cottonwood of similar age -- several wind damaged -- near the existing pedestrian bridge.

Riparian trees dominated by black cottonwood of similar age near the fish ladder north of CRDT.



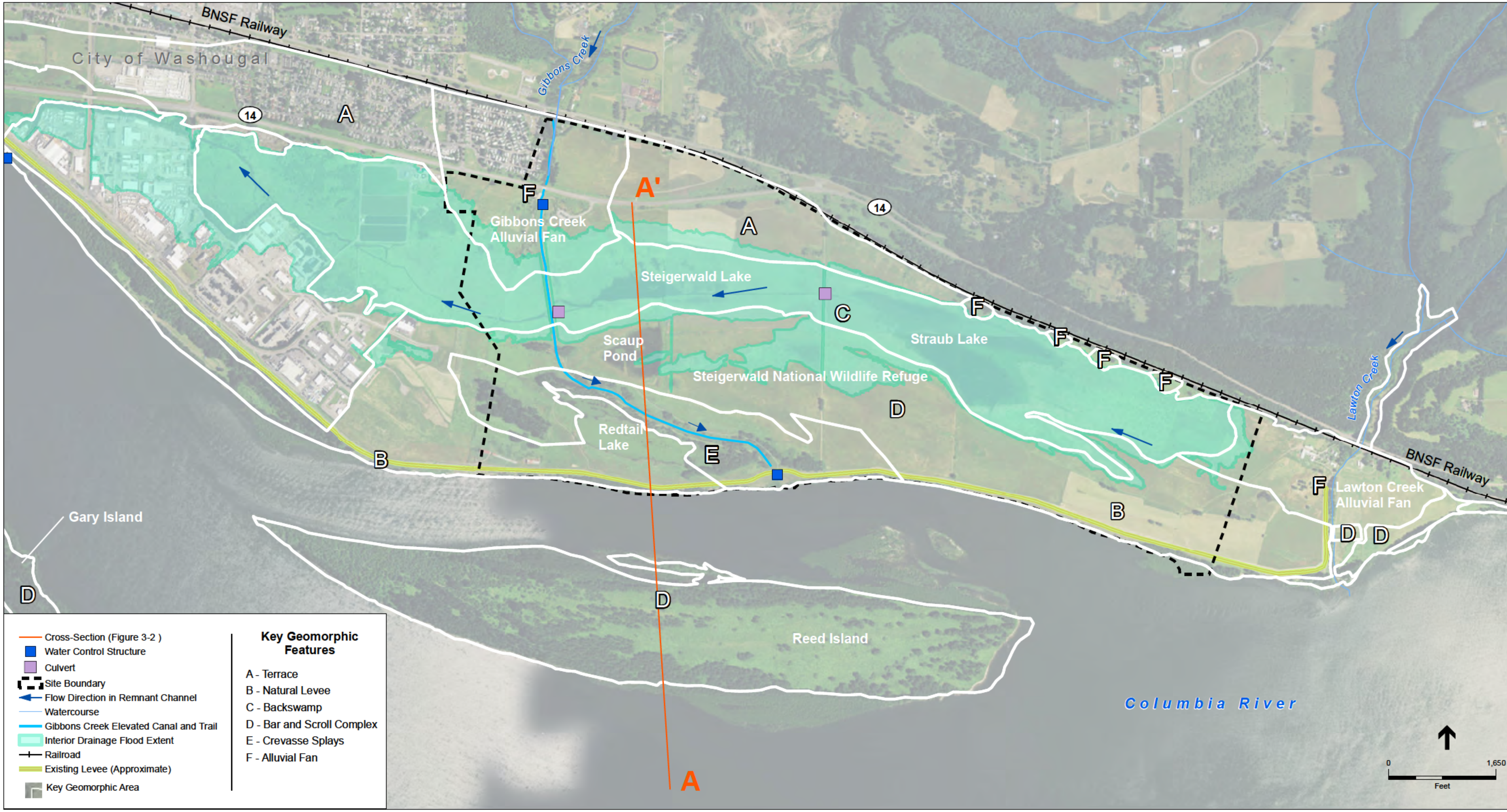
Columbia River riparian corridor at the east end of the CRDT is a narrow cottonwood stand.

Riparian trees along the north side of Redtail Lake are mature sparce cottonwood.

Steigerwald Floodplain Design

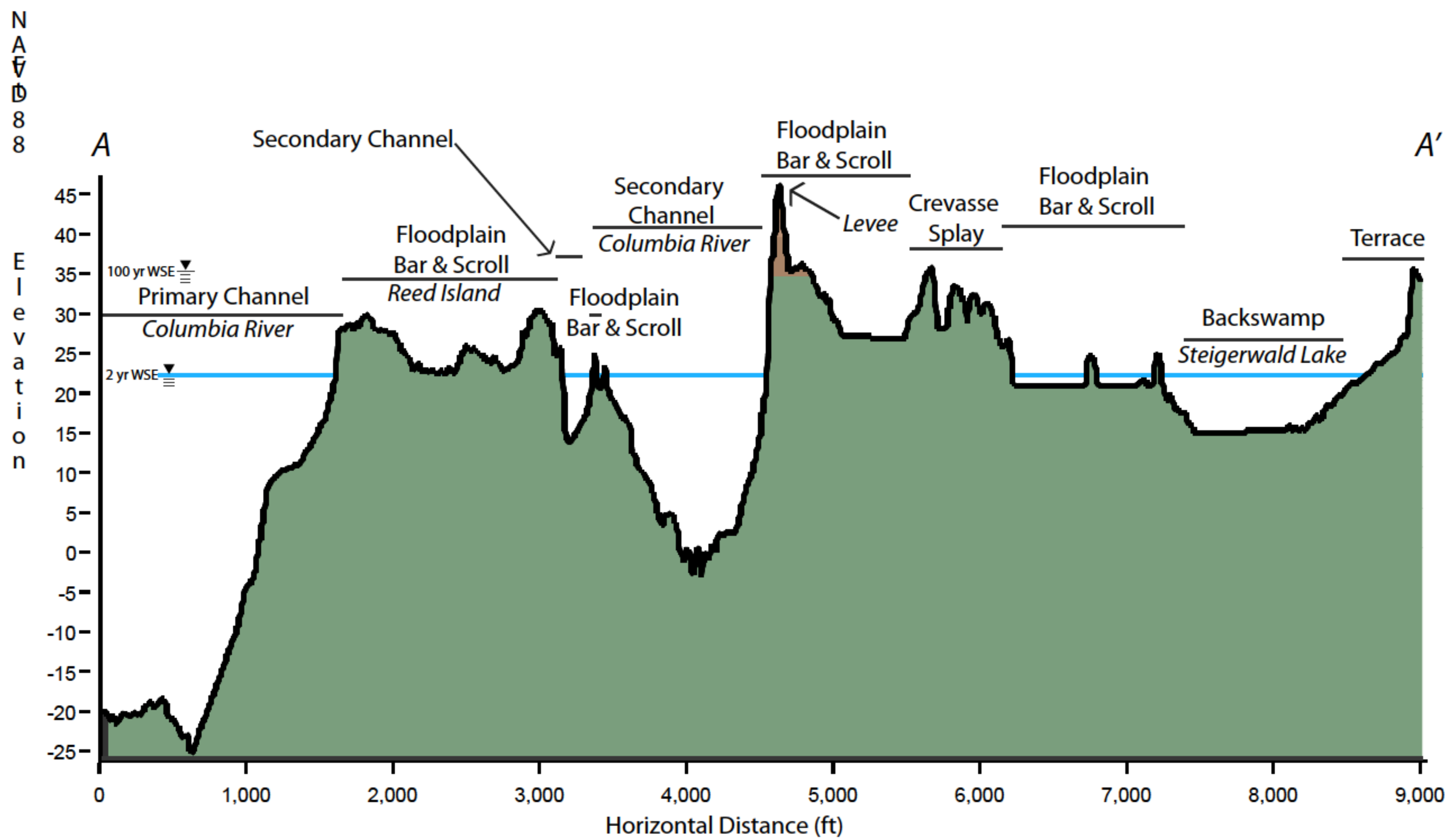
Figure 2-3

Existing Riparian Vegetation.



SOURCE: Estuary Partnership, 2013; Clark County; National Hydrography Dataset; USACE LiDAR, 2012
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 3-1
Key Geomorphic Features
Washougal, Washington



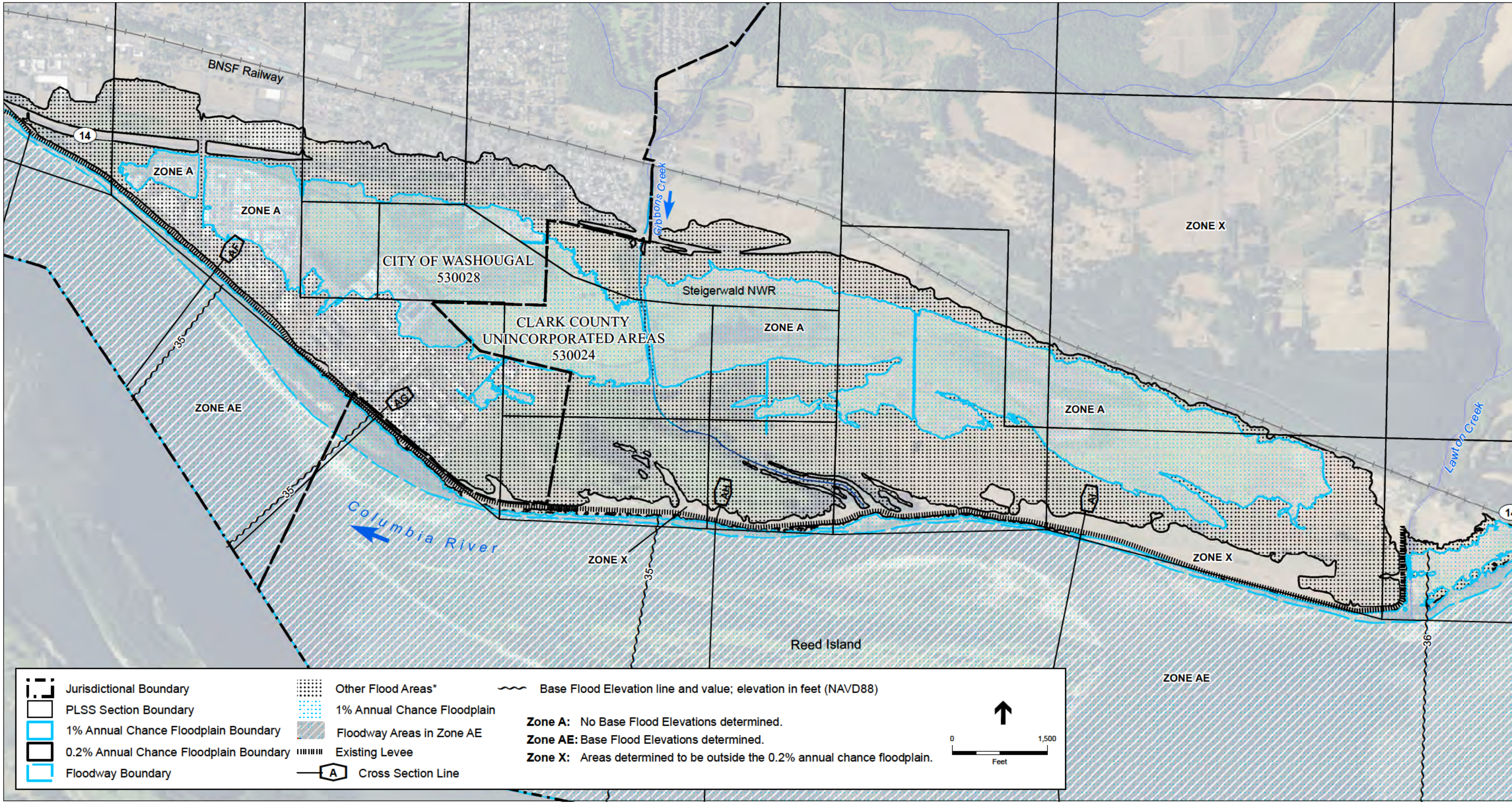
SOURCE: USACE LIDAR, 2010; CREEC 2014

Steigerwald Restoration Design

Figure 3-2

Site Cross Section (2010 LIDAR)

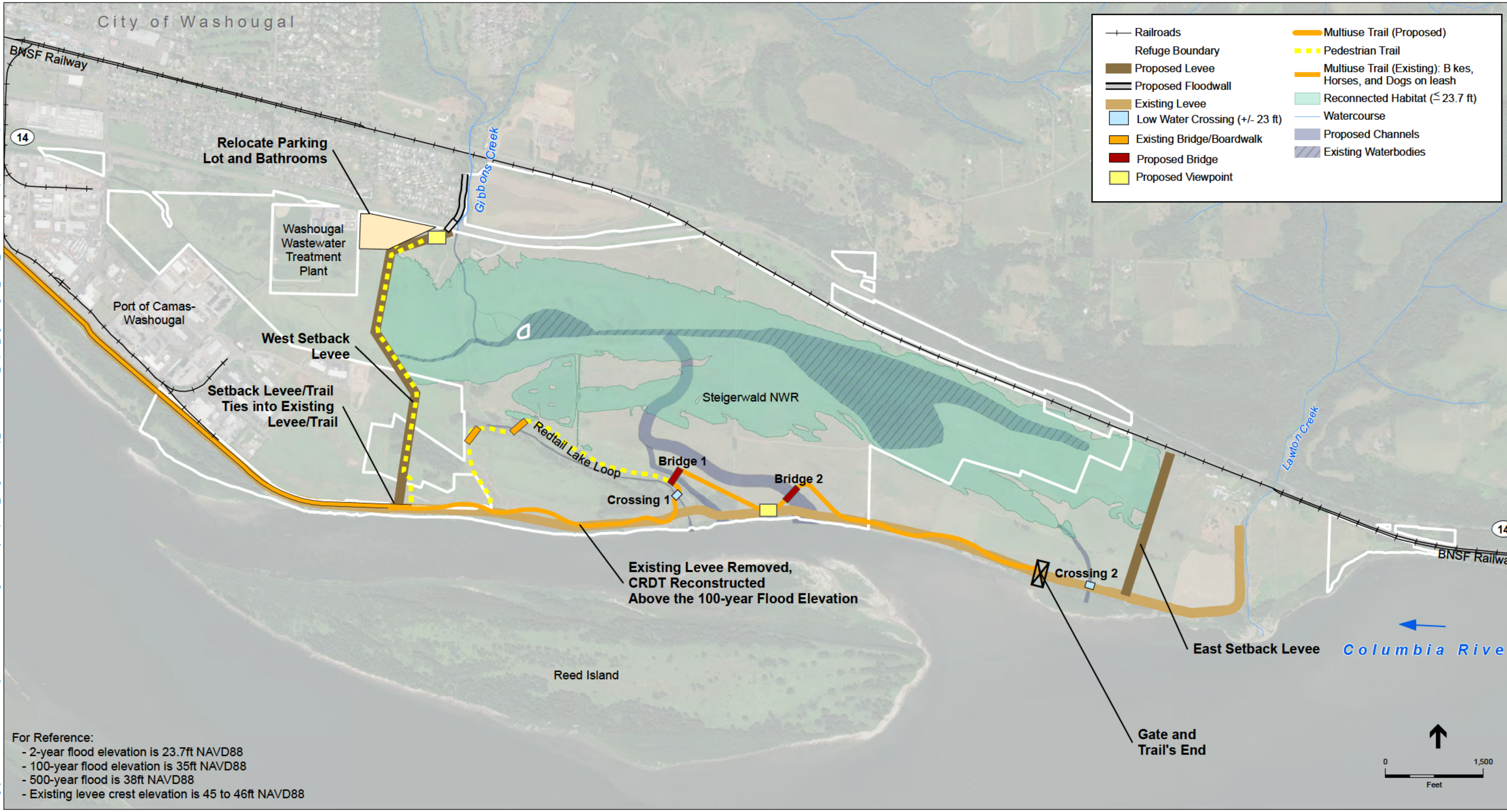
Washougal, Washington



SOURCE: Estuary Partnership, 2013; Clark County; National Hydrography Dataset; FEMA 2015 (Panels: 0553D, 0554D, 0560D, 0562D, 0570D); NAIP, 2014.

* Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

Figure 3-3
Existing Floodplain Mapping of Project Area
Washougal, Washington



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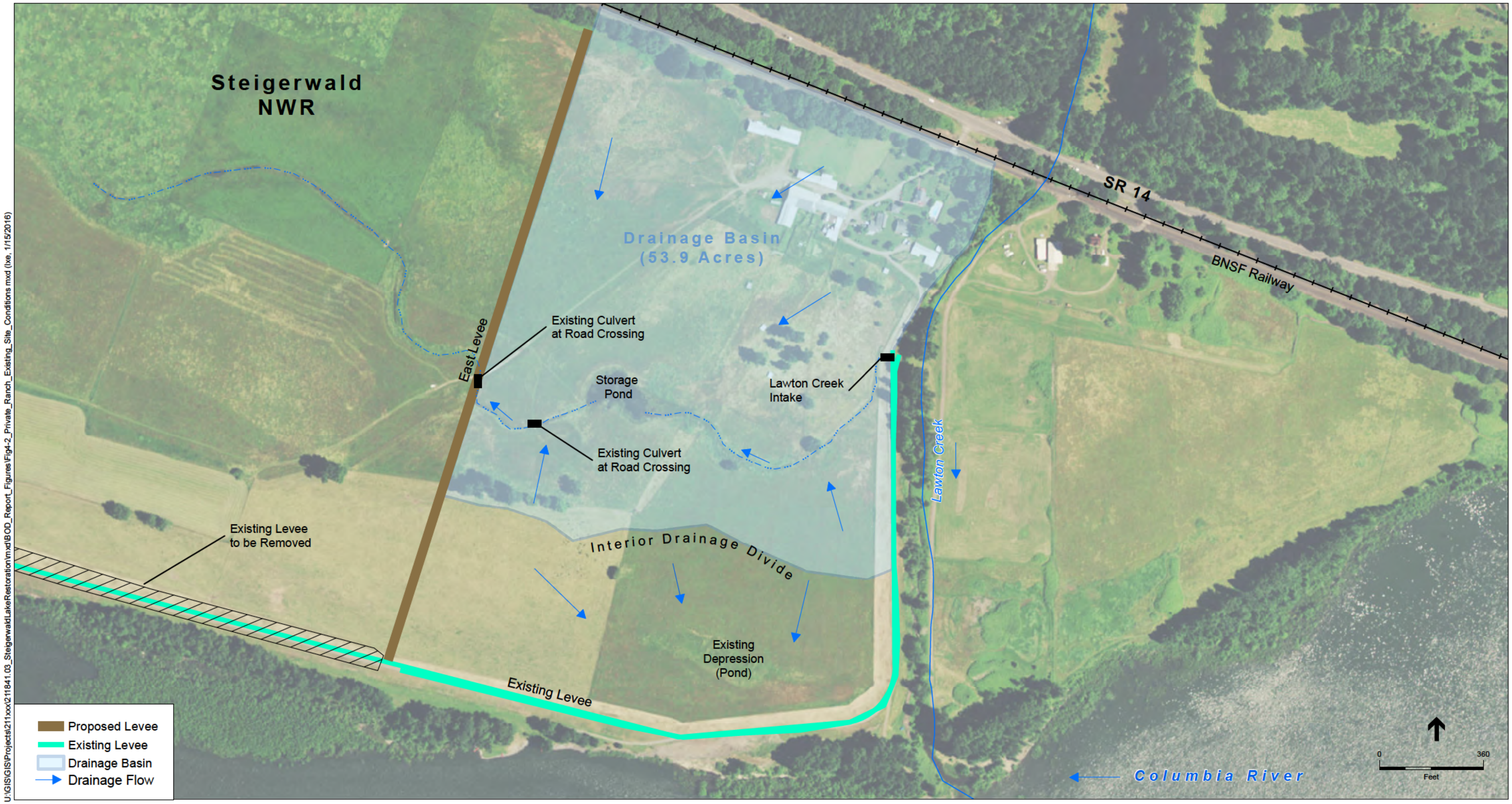
SOURCE: Estuary Partnership, 2013; Clark County; Na ional Hydrography Dataset; USACE LiDAR, 2010
Service Layer Credits: ESRI 2013

Steigerwald Restoration Design

Figure 4-1
Summary of Public Access Features
Washougal, Washington



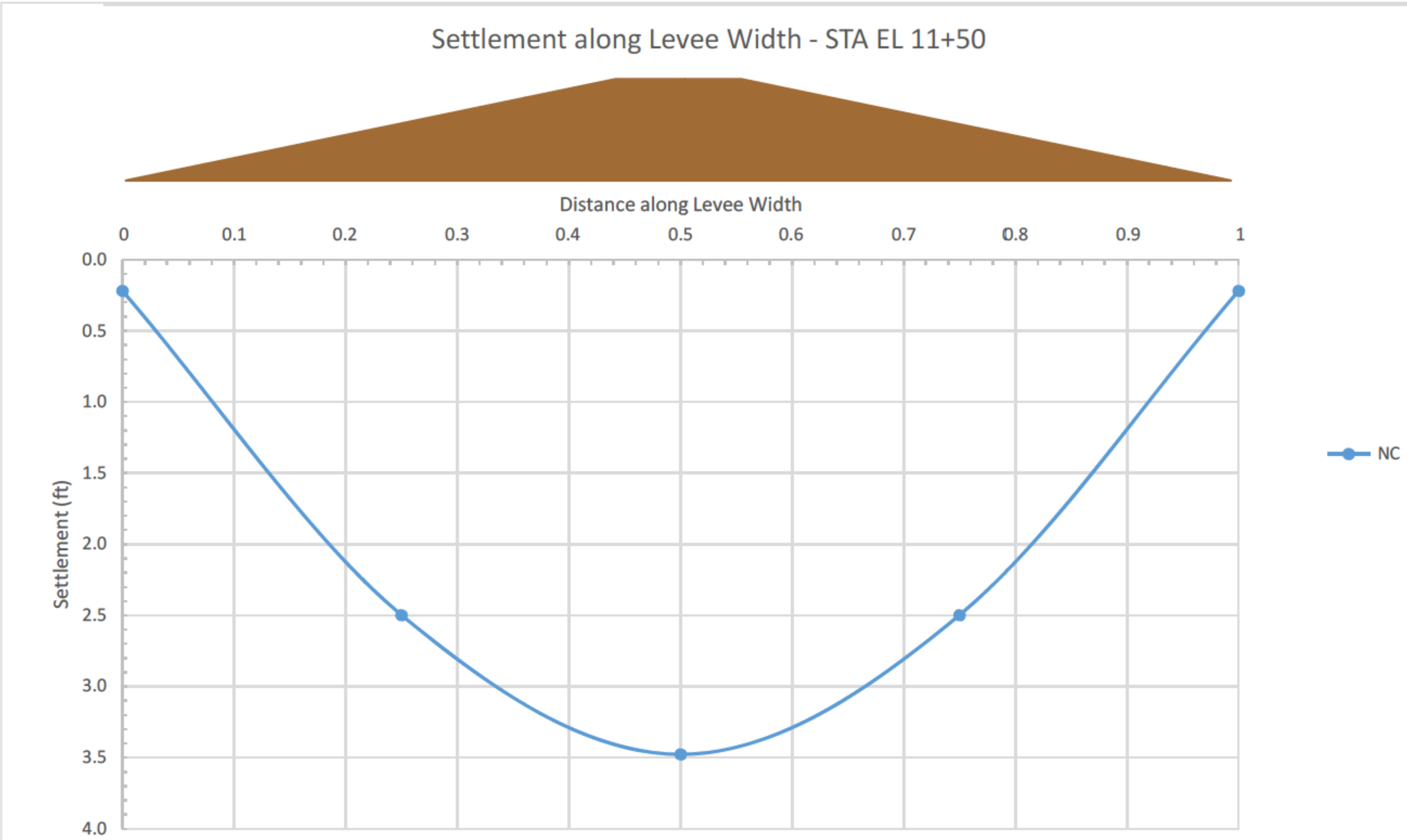
SOURCE: Estuary Partnership, 2013; Clark County; National Hydrography Dataset; USACE LiDAR, 2012
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Ear hstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Steigerwald Restoration Design

Figure 4-2
Private Ranch Drainage Features
Washougal, Washington

Assumes levee is symmetrical about centerline with 4H:1V slopes

	Settlement along Levee (ft) for x/2b =				
	0	0.25	0.5	0.75	1
NC	0.22	2.50	3.48	2.50	0.22



Source: Cornforth 2015

Steigerwald Restoration Design

Figure 4-3

Levee Settlement

APPENDIX A

CONSTRUCTION DRAWINGS

APPENDIX B
SURVEY REPORT

B-1 Survey Report

B-2 Supplemental Survey of SR14

APPENDIX C
GEOMORPHIC ANALYSES

C-1 Columbia River Geomorphic Analysis Technical Memorandum

C-2 Gibbons Creek Geomorphic Analysis Technical Memorandum

APPENDIX D

HYDROLOGIC AND HYDRAULIC ANALYSES

APPENDIX E
GEOTECHNICAL ANALYSIS

APPENDIX F

STURCTURAL ANALYSIS

APPENDIX G

ROADWAY ANALYSIS

APPENDIX H

OPINION OF CONSTRUCTION COSTS